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TROPICAL AGRICULTURIST

AGRICULTURAL JOURNAL OF CEYLON

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CEYLON

VOLUME CXIII NUMBER 4
OCTOBER-DECEMBER, 1957

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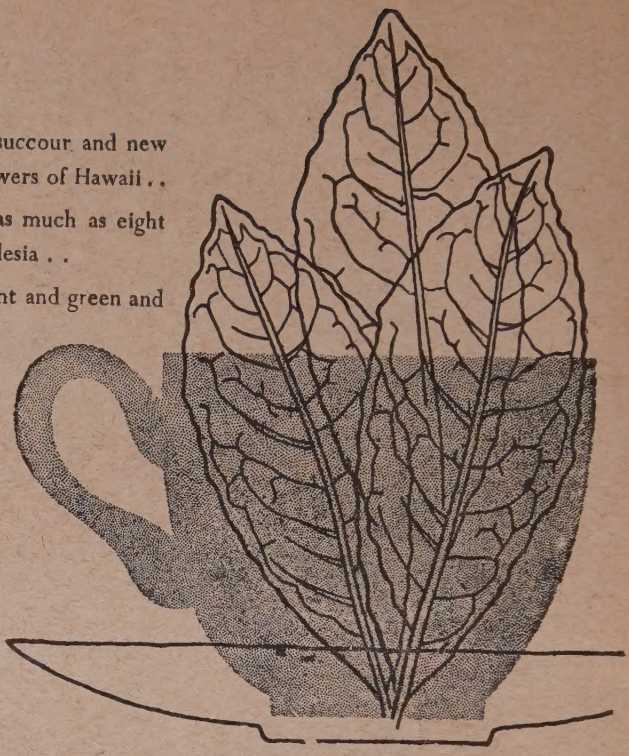

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TROPICAL AGRICULTURIST

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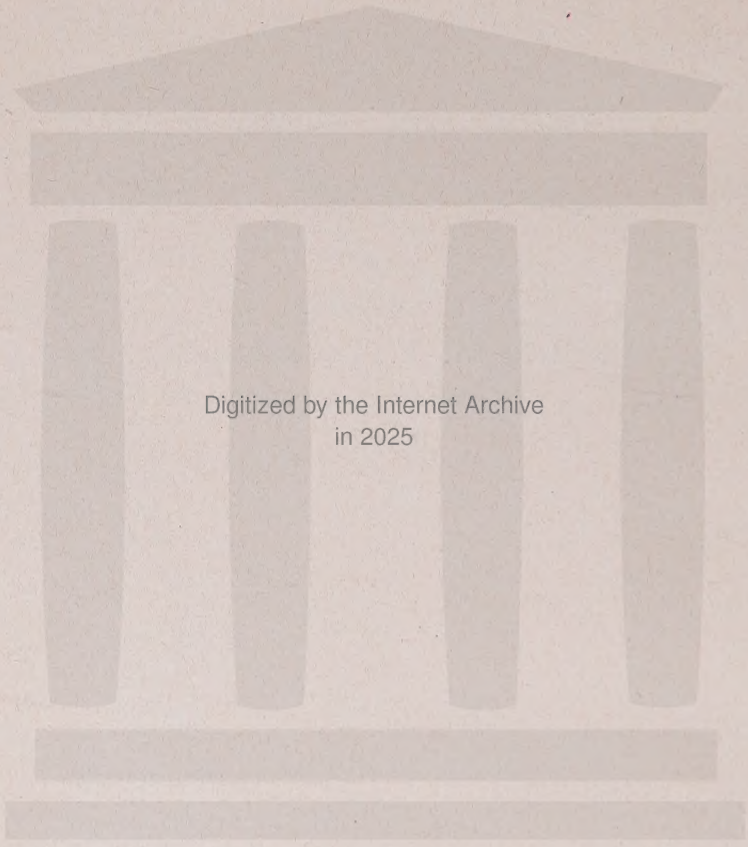
Director of Agriculture

CEYLON DEPARTMENT OF AGRICULTURE



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3—J. N. R 23292 (3/58)

ERRATA

Tropical Agriculturist, Vol. CXIII, p. 133, line 40 should read as follows :—*use of herbicides. Of these methods only trash mulching and the use*

Tropical Agriculturist, Vol. CXIII, p. 135, line 20—read *marketed* for *marked.*

EDITORIAL

Potentialities for Groundnuts

THE WORLD harvest of groundnuts in 1955-56 approximated 13 million tons, and covered over 31 million acres, the totality of which was in the tropics and sub-tropics. Roughly one-third of the groundnut crop is consumed directly as food. The balance provides the world's chief source of edible vegetable oil ; modern crushing techniques give an average extraction rate of 45 per cent. oil.

Ceylon's groundnut acreage has not, in recent years, exceeded 400 and has been confined almost exclusively to Vavuniya, Kilinochchi, Batticaloa and Gal Oya. Extensive areas with a soil and climate that should be eminently suitable for groundnuts, however, exist in the North-Central Northern and Eastern Provinces, and a striking expansion of the acreage under the crop appears both possible and desirable.

The requirements in rainfall are about 25 inches well distributed over at least 14 weeks. Lack of rain in the later stages of growth depresses pod size and yield, and raises harvesting costs. If precipitation is excessive, seeds may sprout before harvest. A soil which is relatively sandy in the surface layers and becomes progressively heavier with depth provides the ideal texture. Heavy clays are completely unsuitable. Although the optimum reaction is somewhat on the acid, side, the crop can be raised successfully over a widge range of *p*H values.

In trials, at Maha Illuppallama, Vakaneri and Gal Oya, in the *maha* season, harvests of rain-fed groundnuts have averaged 900—1,000 lb. of unshelled nuts per acre ; these yields would be considered satisfactory in any tropical country. In *yala*, on well-drained, light-textured soils, with sprinkler or gravity irrigation, it should be possible to raise successful groundnut crops in almost any part of Ceylon's dry zone. With about one acre-foot of irrigation water, yields of over 3,000 lb. of unshelled nuts per acre have been recorded in experimental plots in the Eastern Province. In most countries, the use of the best techniques do not provide yields of over 2,000 lb. per acre.

Although leaf-spot and black-leg occur, no serious fungus disease afflicts the groundnut crop in Ceylon. It should, however, be noted that the ubiquitous *Bacillus solanacearum* may constitute a serious hazard when the acreage expands. The resistance of the species *Arachis nambyquarae* to bacterial wilt warrants its inclusion in variety trials, and its use in breeding programmes.

Variety trials at Maha Illuppallama, Gal Oya and Vakaneri have demonstrated the pre-eminence of the varieties *Uganda Erect* and *Red Spanish*. Apart from the high yield of nuts and the satisfactory shelling out-turn, the kernels of these two varieties contain about 35 per cent. linoleic acid ; African varieties contain under 30 per cent. The content in linoleic acid determines the hydrogenation properties of the oil and its suitability for margarine manufacture. The oil content of these and other varieties tested at Maha Illuppallama, however, have not exceeded 45 per cent. ; early Indian varieties analyse 47 per cent. oil.

Tests at Maha Illuppallama and Vakaneri revealed no response to direct manuring (both artificials and bulky organics). The absence of response to direct application of fertilizers is common in groundnut cultivation in many countries. Groundnuts are nevertheless an exhausting crop that drains soil reserves of particularly potash and lime. There is frequently response by the groundnut crop to fertilizers applied to a previous crop in the rotation. Groundnuts should follow a heavily manured crop, and need not itself receive direct fertilizers. It should, however, not recur in a rotation more often than, say, once in three years.

Notwithstanding the high lime requirement of groundnuts, soils should not be over-limed as unavailability of trace elements may result. Groundnuts at Maha Illuppallama have shown response to molybdenum and sulphur. At Maha Illuppallama, under conditions where only tillage operations were mechanized, cultivation costs averaged Rs. 245 per acre. At the present guaranteed price of 44 cents per lb. of unshelled nuts, and a yield of 800 lb. per acre, the gross income approximates Rs. 352 per acre. All stages in the cultivation and processing of groundnut—including planting, weeding, harvesting, drying and decorticating—can be completely mechanized, and a striking increase in profits should then be possible. It should be indicated, in this connexion, that in countries which grow groundnuts commercially, producer prices are markedly lower than the price guaranteed by the Ceylon Government to local growers. In West Africa, prices guaranteed to the producer during the period 1951-57 have fluctuated around £36 per ton of shelled nuts, i.e., about 22 cents per lb.

A groundnut acreage of only 2,500 is all that is required for the total elimination of Ceylon's annual imports of nearly 12,500 cwt. of nuts and nearly 500 cwt. of oil. The Department of Agriculture envisages the establishment of this acreage in 1960. Further expansion of groundnut growing will be determined by Government policy in regard to industrial utilization of groundnut oil, and by Ceylon's ability to compete in export markets. As groundnut cake makes excellent cattle feed, exports should be limited to oil.

STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

2. The " Cinnamon Sand " on Horrekelly Estate (A) Preliminary Experiments

By T. B. PALTRIDGE and K. SANTHIRASEGARAM
(Coconut Research Institute, Ceylon)

1. INTRODUCTION

THIS is a paper in a series emanating from the C.R.I. Division of Agronomy, and published under a common title, viz.—' Studies on the Nutrient Status of some Coconut Soils in Ceylon'. No. 1 in that series (C.R.I. bulletin No. 11) recorded data from experiments with the '*Lateritic Gravel*' on Bandiripuwa Estate, and this paper records data from experiments with the '*Cinnamon Sand*' on Horrekelly Estate. The objectives and the techniques employed were in all respects similar to those described in our first publication.

This soil was selected as one of the poorest coconut soils in Ceylon, typical of large areas along the Western Coast. It is essentially a leached sand, developed through emergence of sub-coastal lagoons, or possibly in low-lying areas that were not necessarily completely submerged at any time. There is generally a ' hard-pan ' or clay layer occurring at a depth of approximately five feet. Drainage is poor, and in wet seasons free water rises to within six inches of the surface.

In order to provide uniform material for use in pot experiments, a number of samples was collected from a typical area on Horrekelly Estate, and transported to the laboratory, where they were thoroughly mixed. Individual samples included all material above a depth of nine inches, but the coarser vegetable matter (stems, leaves and larger roots) were subsequently removed.

That soil was then used to fill a number of six inch, polysterene flower pots :—each containing approximately 2,000 gms. (dry weight), and the response to any nutrient was measured in terms of the dry weight of plants grown in every pot. All pots were watered daily ; their water content being brought to a constant level (85 per cent. field capacity) by weight. In order

to avoid contamination, that water was filtered, passed through a commercial water softener, distilled and re-distilled before use. The final distillation was in ' Pyrex ' glass.

The test plants were a perennial pasture grass (*Paspalum commersonii Lam*) and two legumes (*Phaseolus lathyroides L* and *Medicago sativa L*).

2. EXPERIMENTAL

Experiment 1

(*a*) *Objective.* Preliminary observations on the nutrient status of a leached sand.

(*b*) *Design* and *Procedure.* This was a simple $2^2 \times 3^1$ factorial experiment, using two species (*Paspalum commersonii* and *Phaseolus lathyroides*) and the following combined nutrients :—

1. Major nutrients (N. P. K.).
2. Minor nutrients (Mg. Cu. Zn. Mn, Fe, B and Mo).
3. $CaCO_3$, applied at 10 cwt./acre
4. $Ca(OH)_2$, applied at 831 lb. acre

} = 4 cwt. acre of Ca.

The calcium salts were mixed with the upper two inches of soil. All other nutrients were applied in forms and doses enumerated in *Table I.*

TABLE I.—*Forms and rates of fertilizer application in Experiment 1*

Designation	*Chemical*	*Rate of Application/Acre*
K	K_2SO_4	1.5 cwt. = 75 lb. K + 35 lb. S
P	$NaH_2PO_4.2H_2O$	3 cwt. = 67 lb. P + 49 lb. Na
N	$(NH_4)_2SO_4$	5 cwt. = 118 lb. N + 135 lb. S
Mg	$MgSO_4.7H_2O$	0.5 cwt. = 6 lb. Mg. + 7 lb. S
Zn	$ZnSO_4.7H_2O$	7 lb. = 1·5 lb. Zn + 0·8 lb. S
Mn	$MnSO_4.4H_2O$	14 lb. = 3·5 lb. Mn + 2·0 lb. S
Fe	$FeSO_2.7H_2O$	14 lb. = 2·8 lb. Fe + 1·6 lb. S
Cu	$CuSO_4.5H_2O$	7 lb = 1·8 lb Cu + 0·9 lb. S
Mo	$(NH_4)_6Mo_7O_{24}.4H_2O$	1.4 lb. = 0·5 lb. Mo + 0·7 lb. N
B	$Na_2B_4O_7.10H_2O$	4.4 lb. = 0·5 lb. B + 0·5 lb. Na

The experiment was planted on 12th May, 1956, and both species were harvested simultaneously on 4th July and on 11th August, 1956.

(*c*) *Results.* Individual yields and effective treatments are shown in *Table II.*

TABLE II. EXPERIMENT 1. *Showing individual yields and level of significance for all treatment affecting the yield of two aspects*

Harvest	*Species*	*Treatment*	*Nil*	*Minor*	*Major*	*Majors + Minors*	*Effective Treatments*	*Level of Significance %*
(1)	PAS-	Nil	0.44	0.82	11.82	12.07	Species	5.0
	PA-	$Ca(OH)_2$	1.07	1.20	8.78	14.68	Ca	1.0
Age	LUM	$CaCO_3$	0.48	0.83	20.23	20.68	Majors	0.1
53								
Days	PHA-	Nil	1.04	2.58	1.46	1.87	Sp × Maj.	1.0
	SEO	$Ca(OH)_2$	2.06	1.11	7.40	14.68	Ca × Maj.	1.0
	LUS	$CaCO_3$	1.63	0.85	11.99	15.26		
(2)	PAS	Nil	0.42	0.31	0.79	0.17	Ca	1.0
	PA-	$Ca(OH)_2$	0.54	0.42	15.94	17.40	Majors	0.1
Age	LUM	$CaCO_3$	0.28	0.34	10.81	15.85	Minors	5.0
91								
Days	PHA-	Nil	0.77	0.70	0.13	0.64	Ca × Maj.	1.0
	SEO	$Ca(OH)_2$	0.92	0.68	2.32	15.67	Sp × Maj.	5.0
	LUS	$CaCO_3$	0.85	0.72	1.32	12.45	Maj. × Min.	5.0

The data show that all three treatments, Ca, Majors and Minors, were necessary for satisfactory growth of plants in this soil. Their effects were very pronounced (see Fig. 1 and Plate 1).

Calcium, alone had very little effect, but Ca in association with N, P and K, gave a very great increase in yield, ranging from 1187 per cent. for Ca $(OH)_2$ to 1561 per cent. for $CaCO_3$ (mean values for cumulative yields of both species). Also, it should be noted that in absence of Ca, the corresponding increments for NPK were as little as 72 and 21 per cent.

With the grass (*Paspalum*) there was no significant effect from absence of minor elements, but with the legume, and in presence of Ca, there was a very big response (see *Table III*).

TABLE III. EXPERIMENT 1. *Showing relative yields for two species and three treatments*

Species	*Nil*	*Ca + Majors*	*Ca + Majors + Minors*
Paspalum	100	3,160	3,960
Phaseolus	100	230	3,120
Mean	100	1,695	3,540

Fig. 1

EXPERIMENT 1. Diagram showing individual and cumulative yields from 12 treatments and from 2 harvests.

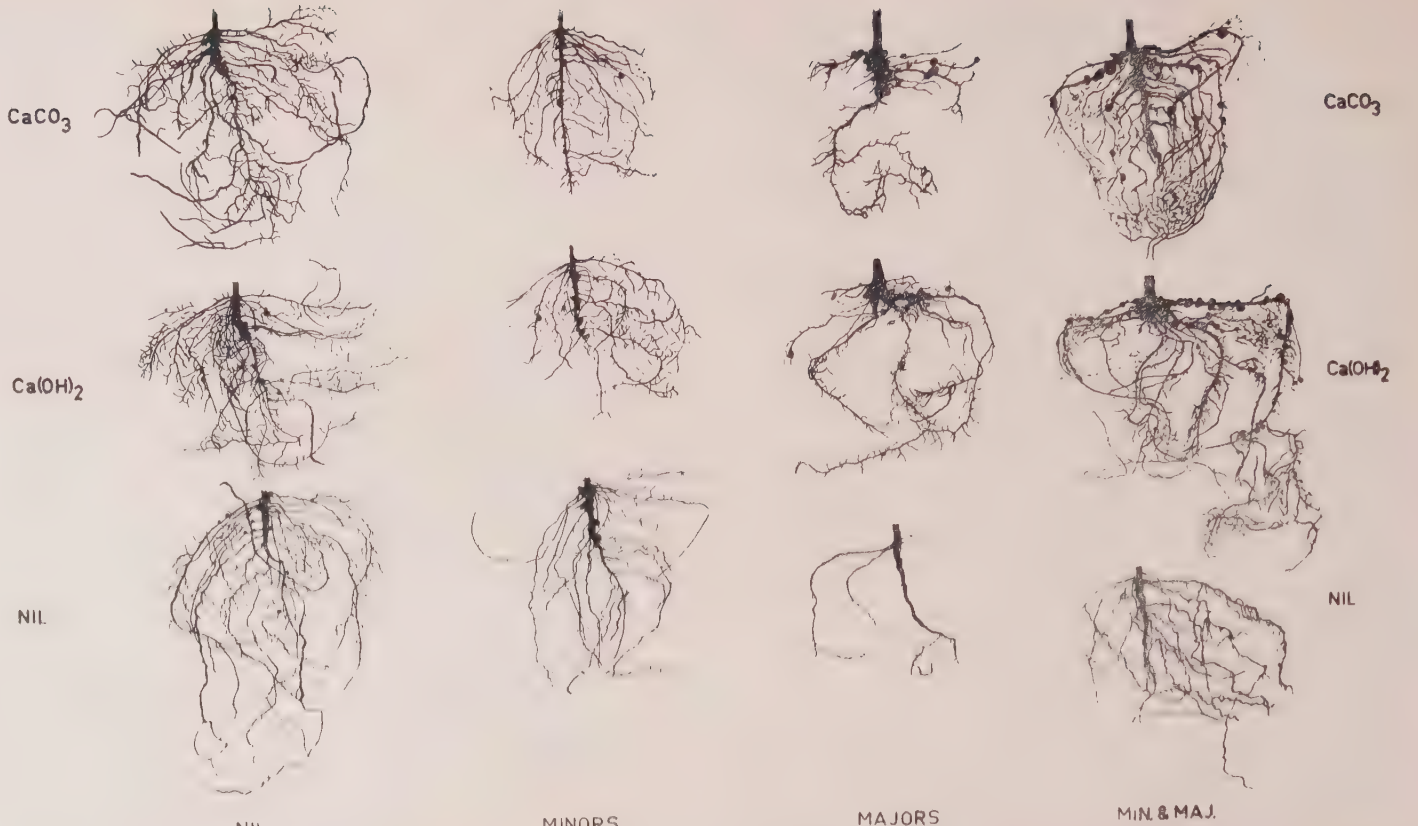


Fig. 2. Experiment I. *2nd Harvest.* Root systems of *Phaseolus lathyroides* grown in 'cinnamon sand', with and without Calcium ($CaCO_3$ or $Ca(OH_2)$), major nutrients (N, P and K), and minor nutrients (Mg, Cu, Zn, Mn, Fe, B and Mo)

It is a point of some importance that in the second harvest, and in absence of Ca, 'Major + Minor' tended to decrease the yield of both species, and plants of *Paspalum* died.

After the second harvest, all plants in this experiment were uprooted, and their root systems compared. Those from plants of *Phaseolus* are shown diagrammatically in Fig. 2.

Any effect from the several nutrients was very similar to that recorded for the above ground tissues. They are summarized in Appendix 1.

(*d*) *Discussion.* This experiment showed that plants grown in cinnamon sand would suffer from a deficiency of both major and minor elements. Moreover it was apparent that application of N, P and K alone, would be largely ineffective; that it would have an adverse effect on root growth; and that it might lead to the death of desirable pasture plants. Application of calcium and some minor elements would be a necessary pre-requisite to any satisfactory response to the major nutrients.

The amount of calcium required and optimal dosage of other major nutrients were therefore matters of first importance, and in order to gain that information some experiments with increasing amounts of Ca, Mg., P and K were carried out, before proceeding with any study on trace element deficiencies.

Experiments 2 and 3

(*a*) *Objective.* To determine the optimum dosage of Ca, P, K and Mg.

(*b*) *Design and Procedure.* These were two comparatively simple 4^2 factorial experiments, each with two replicates of all treatments. In *Experiment* 2, Ca. was applied as $CaCO_3$ (nil, $2\frac{1}{2}$, 5 and 10 cwt./acre), and P. as $NaH_2PO_4.2H_2O$ (nil, $1\frac{1}{2}$, 3 and 6 cwt./acre). All pots received a basal dressing of K. (6 cwt. K_2SO_4/acre), N. (5 cwt. $(NH_4)_2SO_4$/acre), and Mg. (6 cwt. $MgSO_4.7H_2O$/acre).

In *Experiment* 3, K. and Mg. were applied as K_2SO_4 (nil, $1\frac{1}{2}$, 3 and 6 cwt./acre) and as $MgSO_4.7H_2O$ (nil, $1\frac{1}{2}$, 3 and 6 cwt./acre) and all pots received a basal dressing of Ca. (10 cwt. $CaCO_3$/acre), P. (6 cwt. $NaH_2PO_4.2H_2O$/acre), and N. (5 cwt. $(NH_4)_2SO_4$/acre).

Both experiments were planted on 16th August, 1956, and harvested three times, i.e., on 2nd October, 2nd November and 10th December, 1956. All plants were grown from seed and seedlings in excess of two; uniform plants per pot were removed as they appeared. On 5/9/56 the number of plants was reduced to one per pot and those removed (designated 'thinnings') were weighed to give some additional data.

After the first harvest, all plants showed obvious symptoms of nitrogen deficiency, and on October 18th, a further 5 cwt./acre $(NH_4)_2SO_4$ was added to all pots. That addition had an immediate and adverse effect, and a number

of leaves on all plants developed large, greyish coloured lesions at the tip and along their margins, and in some cases extending over the whole leaf blade. Within those lesions all tissues were flaccid and obviously moribund. They did not recover.*

(*c*) *Results.* There were no significant differences between replicates, and cumulative yields for all treatments and for three harvests are recorded in Table IV and V.

TABLE IV. EXPERIMENT 2. *Showing cumulative yields for three harvests, and level of significance for all treatments affecting the yield of* Paspalum commersonii. *n.b. yields recorded to nearest 1·0 gm. only*

Treatment	P 0	P 1½	P 3	P 6	Total	Effective Treatments	Level of Significance, %
Ca 0	13	11	11	13	48	Ca	0·3
Ca 2½	18	25	26	22	91	P	1·0
Ca 5	23	42	42	48	155		
Ca 10	21	38	52	50	161		
Total	75	116	131	133	455		

TABLE V. EXPERIMENT 3. *Showing cumulative yields for three harvests, and level of significance for all treatments affecting the yield of* Paspalum commersonii. *n.b. yields recorded to nearest 1·0 gm. only*

Treatment	Mg 0	Mg 1½	Mg 3	Mg 6	Total	Effective Treatments	Level of Significance %
K 0	4	4	6	5	19	K	0·1
K 1½	26	32	33	34	125	Mg	1·0
K 3	33	38	40	40	151		
K 6	40	60	46	47	193		
Total	103	134	125	126	488		

* This effect from late applications of ammonium sulphate has been a serious handicap in a number of experiments with the cinnamon sand, since a majority of plants have developed symptoms of acute nitrogen deficiency and any late application of $(NH_4)_2SO_4$ has caused serious damage to those plants. It has also been recorded in experiments with 'lateritic gravel', but only when there was a deficiency of K; and in experiments with 'lateritic sand', when there was a deficiency of Ca. No completely satisfactory explanation is available, but from a practical point of view it is perhaps worth noting that this trouble can be avoided by adding $(NH_4)_2SO_4$ immediately before a harvest, or by using NH_4NO_3 in place of the sulphate.

The data show that there was a very marked and progressive response to K. and Ca. (maximum increments of 900 and 255 per cent., respectively) and a much smaller response to P. and Mg. (maximum increments of 75 and 30 per cent. respectively). The response to P. appeared to reach an symptote at P 3 and the greatest response to Mg. (increment of 50 per cent.) was from Mg $1\frac{1}{2}$ at K 6.

Apart from this general result, there were some differential effects from individual nutrients in successive harvests, viz.—

Calcium. In the first harvest all three doses of Ca. were equally effective (mean increment of 105 per cent.). In the second harvest there was a progressive effect from increasing dosage (mean increments of 75, 350 and 450 per cent. for Ca$2\frac{1}{2}$, Ca5 and Ca10 respectively). In the third harvest all Ca0 plants were dead, and mean yields were as 0 : 5 : 37 : 61. (See Plate 2).

These data may be expressed in terms of relative yields, as follows :—

	Ca 0	Ca $2\frac{1}{2}$	Ca 5	Ca 10
1st Harvest ..	53	98	124	100
2nd Harvest ..	17	33	78	100
3rd Harvest ..	0	8	60	100
Mean ..	23	46	87	100

Phosphorus. Unlike Ca. phosphorus was most effective in the early stages of growth and least effective in the third harvest. Also, highest yields were recorded from the smaller doses (P$1\frac{1}{2}$ and P3). Mean relative yields were as follows :—*

	P 0	P $1\frac{1}{2}$	P 3	P 6
1st Harvest ..	46	78	89	100
2nd Harvest ..	74	126	134	100
3rd Harvest ..	91	109	126	100
Mean ..	70	105	116	100

Potassium. The response to K. was essentially similar to that for Ca. with all doses equally effective in the first harvest (mean increment of 650

* This result is in conformity with the data from experiments with the 'lateritic gravel' soil (see Paltridge and Santhirasegaram, C.R.I. Bul. 11, 1957). In those experiments there was a big response to P in first harvests and a much smaller response in subsequent harvests.

per cent.) and a progressive effect from increasing dosage in subsequent harvests. In the third harvest all K_0 plants were dead (see Plate 3). Relative yields were as follows :—

	K 0	K 1½	K 3	K 6
1st Harvest ..	15	95	100	100
2nd Harvest ..	12	65	75	100
3rd Harvest ..	0	6	35	100
Mean ..	9	55	70	100

Magnesium. Magnesium had a somewhat complex effect, since in the first harvest there was an appreciable response to Mg 1½ (increment of 30 per cent.) and very little effect from other doses : while in subsequent harvests there was a trend towards increasing yields from increasing dosage. Relative yields were as follows :—

	Mg 0	Mg 1½	Mg 3	Mg 6
1st Harvest ..	95	130	110	100
2nd Harvest ..	60	77	85	100
3rd Harvest ..	45	60	75	100
Mean ..	67	89	90	100

Even within the K6 treatments there was the same pattern of responses, but the progressive advantage from increasing dosage in later harvests was less pronounced, and the greatest over-all benefit was derived from Mg1½ viz.—

	Mg 0	Mg 1½	Mg 3	Mg 6
1st Harvest ..	109	178	109	100
2nd Harvest ..	85	93	93	100
3rd Harvest ..	57	79	84	100
Mean ..	84	123	95	100

(*c*) *Summary of Experiments 2 and 3.* In these two experiments highest yields were obtained from a combination of K6 + Mg1½ (see *Fig.* 3) and from $Ca_{10} + P_3$.

At Ca5, there was some initial advantage from a higher dosage of P. (P 6), but in the data for the third harvest there was a cumulative advantage from Ca10 and no advantage from the higher dose of P. (see *Fig.* 4).

The response to still higher doses of K. and Ca. is reported under *Experiment* 10.

Experiment 4

(*a*) *Objective.* To measure the effect of boron on the growth of plants in cinnamon sand.

Fig. 3. EXPERIMENT 3. Showing cumulative yield of plants grown in ' cinnamon sand ', and with increasing amounts of K .(K_2SO_4) and Mg. ($MgSO_4$. $7H_2O$)

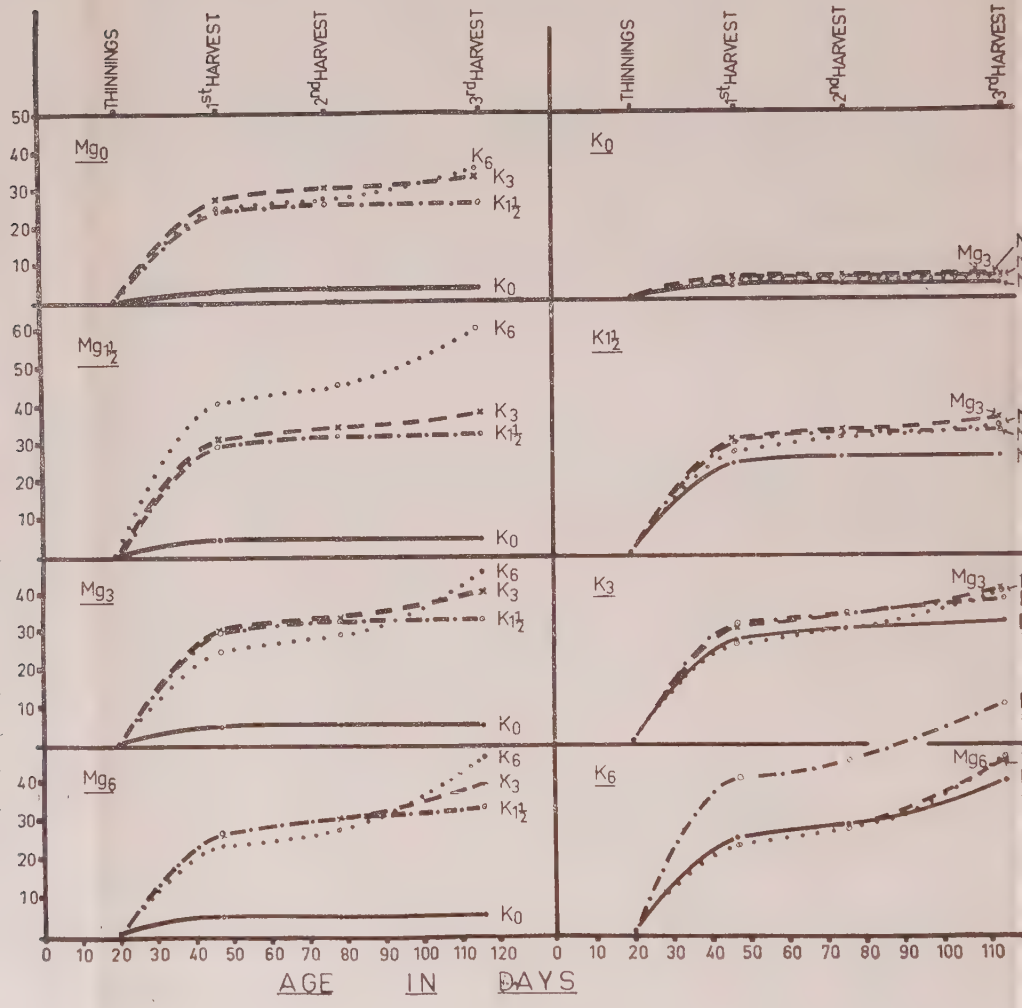
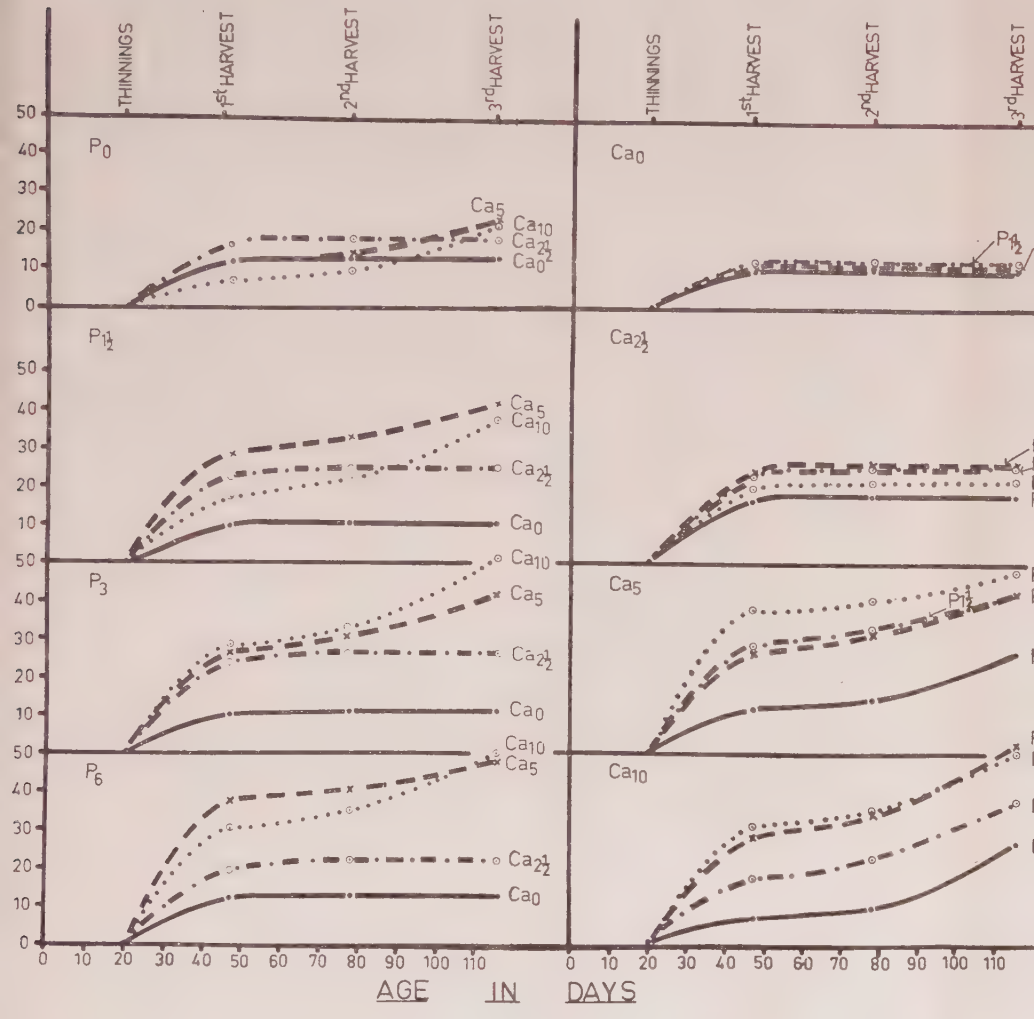


Fig. 4. EXPERIMENT 2. Showing cumulative yield of plants grown in 'cinnamon sand' and with increasing amount of P. ($NaH_2PO_4.2H_2O$) and Ca ($CaCO_3$)



(*b*) *Design and Procedure.* This was a $3^2 \times 2$ factorial experiment using three species (*Paspalum commersonii, Phaseolus lathyroides* and *Medicago sativa*), two levels of manganese, and three levels of boron. There were two replicates (see *Table VI*). All pots received a basal dressing of Ca, N, P, K, Mg, Cu, Zn, Fe and Mo. Calcium was applied as $CaCO_3$ (5 cwt./acre) mixed in the upper $1\frac{1}{2}$ inches of soil. All other nutrients were applied in solution and in forms enumerated in *Table I*, but the dosage of K, P and Mg was increased to 3, 6 and 4 cwt./acre respectively, and both Cu and Zn were applied @ 14 lb./acre. Boron was applied as $Na_2B_4O_7,10H_2O$ in solution, and at rates of 3 and 6 lb./acre. In order to avoid contamination from ' pyrex ' glassware all water used in this experiment was finally distilled from chromium plated, copper apparatus.

The experiment was planted on 10th August 1956. *Paspalum* and *Phaseolus* were harvested on 25/9/56, and the *Medicago* on 13/10/56. Thereafter plants of *Phaseolus* were affected by a virus, and only *Paspalum* and *Medicago* were harvested on 7/11/56 and on 5/12/56. Additional nutrients were added as follows :—

On 27/9/56 1·5 cwt./acre K_2SO_4 was applied to all pots. Total dose now $\equiv$ 225 lb./acre of K., and

On 19/10/56 5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots. Total dose now $\equiv$ 236 lb./acre of N.

(*c*) *Results.* Individual yields from all three species in the first harvest are recorded in *Table VI*.

TABLE VI. EXPERIMENT 4. *Showing individual yields and level of significance for all treatments affecting the yield of three species*

Species	Treatment	REP 1		REP 2		Effective Treatment	Level of Significance %
		Mn 0	Mn 14	Mn 0	Mn 14		
Paspalum	B 0	10.40	10.98	11.12	10.90	B	1·0
	B 3	11.96	10.67	10.83	10.47	Species	0·1
	B 6	10.70	9.66	10.91	10.25	B × Sp.	1·0
Phaseolus	B 0	0.74	1.42	1.03	0.60		
	B 3	1.58	1.57	1.61	1.72		
	B 6	1.66	0.85	1.94	1.33		
Medicago	B 0	1.77	1.18	0.51	1.56		
	B 3	2.03	2.28	2.59	2.73		
	B 6	3.20	3.13	2.92	2.66		

The data showed that there was a marked difference in reaction to boron, as between the grass (*Paspalum*) on the one hand, and the two legumes (*Phaseolus* and *Medicago*) on the other. The yield from both legumes rose steadily with increasing rates of B ; whereas with grass there was a small depression due to boron. By excluding the data for *Paspalum*, the response to boron (in the two legumes) was shown to be significant *a* 0·1 per cent. The data for this, and subsequent harvests of *Paspalum* and *Medicago* were therefore treated separately (see *Table VII*). Cumulative yields for the two species are shown diagrammatically in *Fig. 5*.

Throughout this experiment there was no effect from manganese - indicating that there is no deficiency of Mn. in cinnamon sand.

Experiment 5

(*a*) *Objective.* To measure the e ect of sulphur on the growth of plants in cinnamon sand.

(*b*) *Design and Procedure.* This experiment was a simple comparison of two treatments, ' nil ' and ' sulphur '; using two species (*Paspalum commersonii* and *Phaseolus lathyroides*). There were twelve formulations, comprising six mixtures, containing sulphur and six with no sulphur ; viz.—

(1)	K_2SO_4	+	(NH_4NO_3	+	$MgCl_2$	+	$CaCO_3$)
(2)	$(NH_4)_2SO_4$	+	(KCl	+	$MgCl_2$	+	$CaCO_3$)
(3)	$MgSO_4$	+	(KCl	+	NH_4NO_3	+	$CaCO_3$)
(4)	$CaSO_4$	+	(KCl	+	NH_4NO_3	+	$MgCl_2$)
(5)	H_2SO_4	+	(KCl	+	NH_4NO_3	+	$MgCl_2 + CaCO_3$)
(6)	S_4	+	(KCl	+	NH_4NO_3	+	$MgCl_2 + CaCO_3$)

and

(7)	KCl	+	(NH_4NO_3	+	$MgCl_2$	+	$CaCO_3$)
(8)	NH_4NO_3	+	(KCl	+	$MgCl_2$	+	$CaCO_3$)
(9)	$MgCl_2$	+	(KCl	+	NH_4NO_3	+	$CaCO_3$)
(10)	$CaCO_3$	+	(KCl	+	NH_4NO_3	+	$MgCl_2$)
(11)	HCl	+	(KCl	+	NH_4NO_3	+	$MgCl_2 + CaCO_3$)
(12)	Nil	+	(KCl	+	NH_4NO_3	+	$MgCl_2 + CaCO_3$)

All formulations contained the same amount of K, N, Mg and Ca. The basic treatment was K_2SO_4, 6 cwt./acre ($\equiv$ 301·2 lb. acre of K. and 123·6 lb. acre of S.). All pots received a basal dressing of phosphate (3 cwt./acre $NaH_2PO_4 \cdot 2H_2O$) and boron (13·2 lb. acre $Na_2B_4O7 \cdot 10H_2O$). The experiment was planted on 11th December, 1956. The *Paspalum* was harvested once, on 1st February, 1957. Plants of *Phaseolus* were inoculated on 31st December, 1956 but made rather unsatisfactory growth. They were harvested on 5th March, 1957, left to make new growth, and photographed on 10/4/1957.

TABLE VII. EXPERIMENT 4. *Showing mean yields and level of significance for all treatments affecting the yield of two species in three successive harvests*

Harvest	Treatment	PASPALUM			MEDICAGO		
		Yield	Effective Treatment	Level of Significance. %	Yield	Effective Treatment	Level of Significance %
(1)	B 0	10·86	B (–)	5·0	1·25	B (+)	0·1
	B 3	10·98	Harvest	0·1	2·41	Harvest	0·1
	B 6	10·38			2·98	B × Har.	5·0
(2)	B 0	3·66			0·13		
	B 3	3·99			0·75		
	B 6	2·42			1·46		
(3)	B 0	3·54			0·01		
	B 3	2·57			0·25		
	B 6	3·08			0·78		

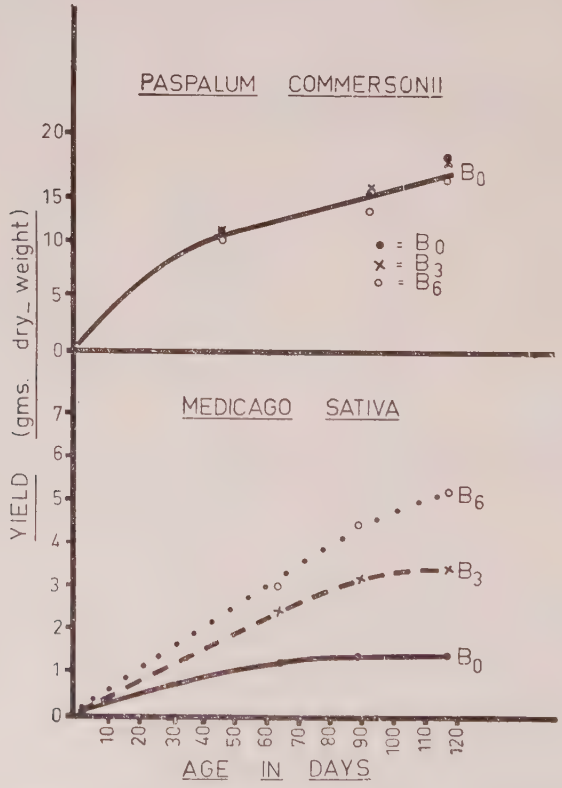


Fig. 5. EXPERIMENT 4. Showing cumulative yields for plants of *Paspalum* and *Medicago* grown in ' Cinnamon Sand ', with increasing amounts of boron.

(*c*) *Results.* Individual yields and *effective* treatments are recorded in *Table VIII.*

TABLE VIII. EXPERIMENT 5. *Showing individual yields from all plants of two species grown with and without sulphur*

Species	Treatment	1/7	2/8	3/9	4/10	5/11	6/12	Effective Treatments	Level of Significance %
PASPALUM	S	8·04	2·45	4·11	0·91	2·73	3·21	S	0·1
	nil	0·30	0·00	0·07	0·05	0·07	0·00	Species	5·0
PHASEOLUS	S	4·71	0·70	3·43	1·11	1·56	0·85	Forms	1·0
	nil	0·14	0·29	0·44	0·47	0·38	0·32		

The data show that there was a very big response to suphur : irrespective of the formulation used. Relative yields, based on mean values for all formulations, were as follows :—

	Nil	Sulphur
Paspalum	1 ..	25·5
Phaseolus	1 ..	08·5
Mean ..	1	17·0

The re-growth on plants of *Phaseolus*, then aged 116 days, is shown in *Plate* 4.

Experiment 6

(*a*) *Objective.* Analysis of minor element deficiencies (other than Mn and B) in plants grown on cinnamon sand.

(*b*) *Design and Procedure.* This was a straight forward $2^6 \times 2$ factorial experiment, using two species (*Paspalum commersonii* and *Phaseolus lathyroides*) and six nutrients (K, Mg, Fe, Mo, Cu and Zn). All pots received a basal dressing of N, P, Ca, B and Mn. Calcium was applied as $CaCO_3$ (5 cwt./acre) mixed in the upper $1\frac{1}{2}$ inches of soil. All other nutrients were applied in solution and in forms enumerated in *Table* 1, but the dosage of K, P and Mg was increased to 3, 6 and 4 cwt./acre, respectively, and both Cu. and Zn. were applied @ 14 lb./acre.*

* This experiment was planted before we had any data from experiments 2 and 3.

The experiment was planted on 16th July, 1956, and additional nutrients were added as follows :—

On 24/8/56 3 cwt./acre K_2SO_4 was applied to all pots with added K.
Total dose now ≡ 150 lb./acre of K.

On 29/8/56 5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots.
Total dose now ≡ 236 lb./acre of N.

Both species were harvested twice : the *Paspalum* on 24/8/56 and 14/9/56, and the *Phaseolus* on 28/8/56 and on 14/9/56.

(*c*) *Results.* In both harvests and with both species there was a very big response to K and a somewhat confusing pattern of much smaller responses to magnesium and the minor elements (see *Fig.* 6.).

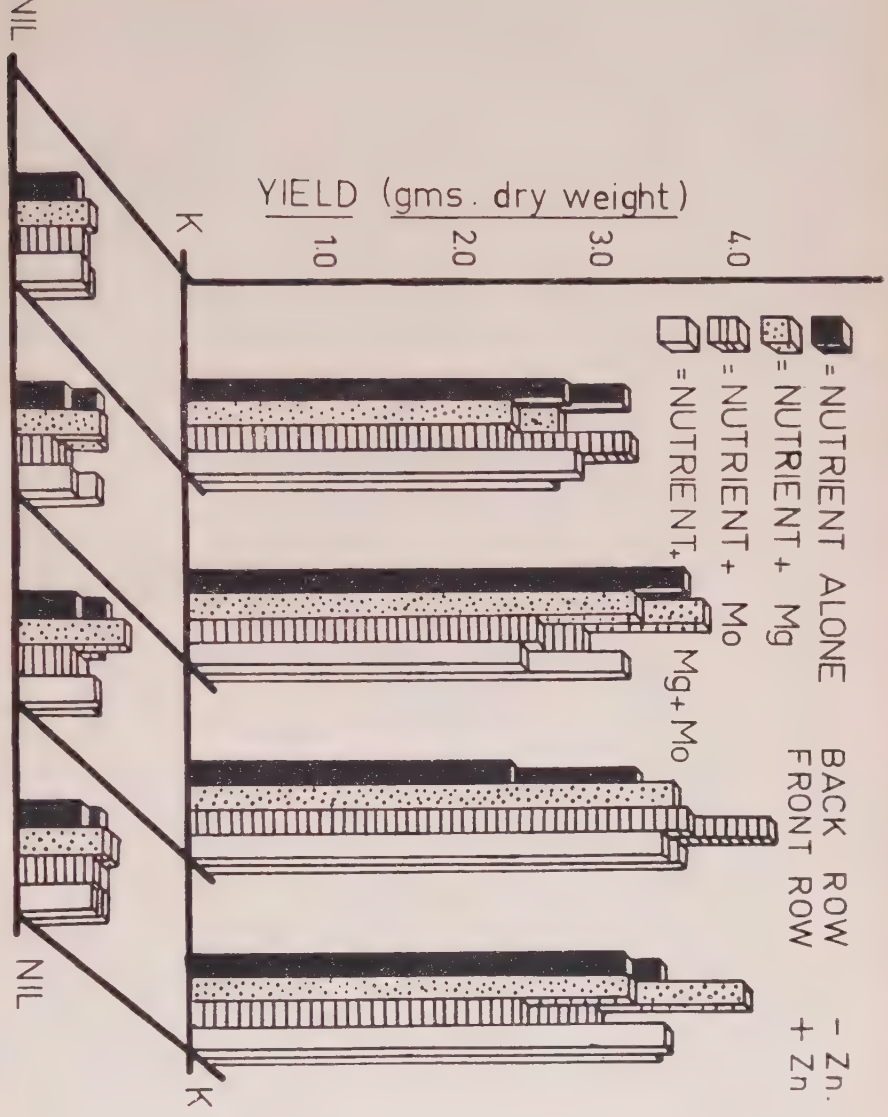
The overall response to K was of the order of + 575 per cent. (based on mean values for all Ko and K + treatments in two harvests). The response to magnesium and to minor elements is recorded in *Table IX.*

TABLE IX. EXPERIMENT 6. *Showing total yields for two harvests of two species n.b. Data for K + treatments only.*

Treatment	Nil	Zn	Cu	Cu + Zn	Effective Treatments	Level of Significance %
NIL nil nil	12.42	10.88	12.70	9.27	Cu	1·0
Mg nil nil	10.53	9.45	13.40	14.02	Zn	5·0
NIL Fe nil	12.28	14.36	13.37	12.54	Fe × Mo	1·0
Mg Fe nil	14.71	12.93	15.82	12.67	Fe × Cu	5·0
NIL nil Mo	12.64	9.31	16.53	14.33		
Mg nil Mo	10.38	11.21	13.99	13.66		
NIL Fe Mo	11.12	9.80	11.42	9.53		
Mg Fe Mo	12.33	9.47	12.19	12.70		

The data show that there was a significant response to Cu. (14 lb./acre $CuSO_4$), and mean yields for both species were increased by 13 per cent. On the other hand Zn. was responsible for some depression in yield :—9 and –11 per cent. for *Paspalum* and *Phaseolus*, respectively. The interaction between Fe. and Mo. was negative.

In both harvests there were highly significant differences between species and in combined data for two harvests of *Phaseolus* there were significant,



Experiment showing cumulative yields from all treatments. *Basal* Ca and B

interactions between Mg, Mc and species. In that data Mg. and Mo. were responsible for small increments of + 21 per cent. for Mg-alone, and a further +7 per cent. Mg. + Mo.*

Experiment 7

(*a*) *Objective.* To study the effect of selected nutrients, K, P, Mg, Fe and Cu in presence of increasing amounts of N. ($(NH_4)_2SO_4$), on plants of *Paspalum commersonii* growing in cinnamon sand.

(*b*) *Design and Procedure.* This was a $2^5 \times 4^1$ factorial experiment using the following nutrients and rates of application :—

K $1\frac{1}{2}$	—	1·5 cwt./acre K_2SO_4
P 3	—	3·0 cwt./acre $NaH_2PO_4.2H_2O$
Mg4	—	4·0 cwt./acre $MgSO_4.7H_2O$
Fe14	—	14 lb./acre $FeSO_4.7H_2O$
Cu7	—	7 lb./acre $CuSO_4.5H_2O$
N $1\frac{1}{2}$	—	1·5 cwt./acre $(NH_4)_2SO_4$
N 3	—	3·0 cwt./acre $(NH_4)_2SO_4$
N 6	—	6·0 cwt./acre $(NH_4)_2SO_4$.

All pots were given a basal dressing of Ca. (5 cwt. acre $CaCO_3$). and B. (3 lb./acre $Na_2B_4O_7.10H_2O$). The $CaCO_3$ was mixed with the upper $1\frac{1}{2}$ inches of soil : all other nutrients were applied in solution. The experiment was planted on 13th September, 1956, and harvested twice, viz.—on 5/11/56 and on 12/12/56.

On 2/11/56 the dose of $CaCO_3$ was increased to 10 cwt./acre (= $CaCl_2$ added in solution) and on 29/11/56 a further 1·5 cwt./acre K_2SO_4 was applied to all pots with added K. (Total dose ≡ 150 lb./acre of K). At that time, and in spite of increasing dosage, all plants showed symptoms of nitrogen deficiency, and the original dressings of $(NH_4)_2SO_4$ were repeated. There again a late application of $(NH_4)_2SO_4$ was followed by adverse effect, and 6 of 8, K_0 N_6 plants died. Other K_0 plants were also affected but subsequently recovered. The K × plants were not visibly affected.

(*c*) *Results.* In both harvests there were very big responses to K. and to N. Mean yields are recorded in *Table X*.

* To some extent these very small responses may have been complicated by adverse effects from the late application of ammonium sulphate on 29/8/56.

TABLE X. EXPERIMENT 7. *Showing mean yields and level of significance for all major level of nutrients affecting the yield of* Paspalum commersonii

Harvest	Treatment		Nil	N 1½	N 3	N 6	Effective Treatments	Significance %
(1) Age 53 Days	Nil	nil	0.49	1.49	2.12	2.55	Harvest	0.1
	P		0.51	2.28	2.59	2.40	K	0.1
	Nil	K	0.48	1.82	4.30	7.04	N	0.1
	P		0.49	3.02	6.99	10.20	Harvest × K	5.0
(2) Age 90 Days	Nil	nil	0.36	0.90	0.86	0.07	Harvest × N	1.0
	P		0.31	0.58	0.26	0.02	N × K	1.0
	Nil		0.40	1.46	1.74	1.60		
	P	K	0.45	1.77	1.91	1.15		

There was no significant effect from P, either alone or in combination with any other nutrient and subsequent analyses were made on the basis of mean values for corresponding treatments with and without phosphate The effects of magnesium and minor elements are recorded in *Table XI.*

TABLE XI. EXPERIMENT 7. *Showing mean yields and level of significance for all treatments affecting the yield of* Paspalum commersonii. n.b. *mean values for* P_0 *and* P + *pots : all with a basal dressing of K, Ca and B.*

Harvest	Treatment			N 0	N 1½	N 3	N 6	Effective Treatments	Level of Significance, %
(1) Age 53 Days	Nil	nil	nil	1.03	3.61	9.89	16.66	Harvest	0.1
			Mg	0.93	5.85	12.05	17.55	N	0.1
		Fe	nil	1.03	4.55	11.18	17.69	Mg	0.1
			Mg	0.95	5.78	12.01	16.93	Cu	5.0
	Cu	nil	nil	1.23	4.25	9.46	17.26	Har × N	0.1
			Mg	1.06	5.60	12.44	18.13	Har × Mg	1.0
		Fe	nil	1.36	3.90	11.28	17.27	Har × Cu	5.0
			Mg	1.02	5.19	11.98	16.55	N × Mg	1.0
(2) Age 90 Days	Nil	nil	nil	0.85	3.27	3.72	1.83	Har × N × Mg	5.0
			Mg	0.86	3.45	3.35	2.66	N × Cu × Fe	5.0
		Fe	nil	0.83	3.50	3.37	3.12		
			Mg	0.68	3.65	2.77	1.89		
	Cu	nil	nil	0.98	3.74	3.29	3.62		
			Mg	0.91	3.84	4.01	3.59		
			nil	0.95	2.11	4.41	3.67		
		Fe	Mg	0.77	2.29	4.27	3.36		

Nitrogen. In the first harvest there was a steadily increasing response to increasing N, and mean relative yields were as 100 : 450 : 1050 : 1600 ; but in the second harvest (i.e. after adding extra $(NH_4)_2SO_4$ on 29/11/56) that response was much smaller and relative yields were as 100 : 375 : 425 ; 350.

Magnesium. In the first harvest there was a significant interaction between nitrogen and magnesium, but this was effective only at the lower doses of nitrogen. Mean relative yields were as follows :—

	N 0	N 1½	N 3	N 6	Total
nil ..	100	100	100	100	100
Mg ..	85	140	115	100	110

In the second harvest there was no significant effect from Mg.

Copper. Unlike Mg, copper had no effect in the first harvest but there was a significant response in the second harvest and at higher levels of nitrogen, viz.—

	N 0	N 1½	N 3	N 6	Total
nil ..	100	100	100	100	100
Cu ..	110	85	120	150	115

Iron. The interaction between Cu, N and Fe was barely significant, and the data showed no real or consistent trend towards any improvement due to Iron.

Experiment 8

(*a*) *Objective.*—To measure the effect of increasing amounts of copper, and of iron and zinc on plants of *Phaseolus lathyroides* grown in cinnamon sand.

(*b*) *Design and Procedure.*—This was a small $2^2 \times 4^1$ factorial experiment, using the following nutrients and rates of application :—

Zn 14	—	14 lb./acre	$ZnSO_4 \cdot 7H_2O$
Fe 28	—	28 lb./acre	$FeSO_4 \cdot 7H_2O$
Cu 7	—	7 lb./acre	$CuSO_4 \cdot 5H_2O$
Cu 21	—	21 lb./acre	$CuSO_4 \cdot 5H_2O$
and Cu 42	—	42 lb./acre	$CuSO_4 \cdot 5H_2O$

All pots were given a basal dressing of N, (5 cwt./acre $(NH_4)_2SO_4$), P. (1½ cwt./acre $NaH_2PO_4.2H_2O$), K. (9 cwt./acre K_2SO_4), Ca. (20 cwt./acre $CaCO_3$), Mg. (1½ cwt./acre $MgSO_4.7H_2O$) and B. (6 lb./acre $Na_2B_4O_7 \cdot 10 H_2O$). The $CaCO_3$ was mixed in the upper 1½ inches of soil, all other nutrients were applied in solution. The legume *Phaseolus lathyroides* was used deliberately to avoid any complications from later application of $(NH_4)_2SO_4$. When the experiment was finished all plants were uprooted, and all were found to be well nodulated.

The experiment was planted on 20th December, 1956. On December, 31st all pots were inoculated with *Rhyzobium*, and the plants were harvested twice, viz.—on 11/2/57 and on 28/3/57.

(*c*) *Results.* Individual yields from all treatments are recorded in *Table XII.*

TABLE XII. EXPERIMENT 8. *Showing individual yields for all treatments*

Harvest	Treatment		Cu 0	Cu 7	Cu 21	Cu 42	Effective Treatments	Level of Significance %
(1) Age 53 Days	nil	nil	3.00	3.84	3.44	2.92	Harvest	5.0
		Zn	3.06	3.38	3.10	3.14		
	Fe	nil	2.85	2.49	2.78	2.81		
		Zn	2.69	3.53	3.29	3.15		
(2) Age 98 Days	nil	nil	2.83	3.41	3.23	2.80		
		Zn	3.41	3.40	3.07	3.61		
	Fe	nil	3.05	3.71	3.60	3.63		
		Zn	3.00	3.80	2.96	3.87		
TOTAL			23.89	27.49	25.47	25.93		

There were no significant differences in yield due to any nutrient.

Discussion on Experiments 4, 5, 6, 7 and 8. These five experiments were designed to study the effect of minor nutrients and of sulphur on plants grown on cinnamon sand. In all cases major nutrients, N, P, K, Ca and Mg were applied as a basal dressing, or as additional 'treatments'. The dosage of N, P and K was generally sufficient to allow optimal growth, but a majority of plants developed symptoms of nitrogen deficiency, and later applications of $(NH_4)_2SO_4$ caused some damage to a number of plants. This was a complicating factor in the interpretation of data from four of these experiments. With one exception (Experiment 8) more than the optional dose of magnesium was applied (see Experiment 3) and this also might be a complicating factor in the interpretation of results.

Two nutrients, sulphur and boron had a major effect on yields. Sulphur was applied at 123 lb./acre, and relative yields for two species were as follows :—

	nil	Sulphur
Paspalum commersonii ..	4 ..	100
Phaseolus lathyroides ..	12 ..	100

Boron had no significant effect on the yield of grass (*Paspalum commersonii*), but a legume (*Medicago sativa*) was greatly affected and relative yields were as follows :—

	nil	Boron 3 lb./acre	Boron 6 lb./acre
1st Harvest ..	42 ..	81 ..	100
2nd Harvest ..	9 ..	51 ..	100
3rd Harvest ..	1 ..	32 ..	100

In two experiments, using *Paspalum commersonii* there was a significant response to copper :—limited to plants receiving heavy doses of nitrogen—, and in one experiment using *Phaseolus lathyroides*, copper had no effect on yield. No visible symptoms of copper deficiency were seen.

Zinc was responsible for a very small depression in yield. Manganese, iron and molybdenum had no real or consistent effect.

The data from these five experiments therefore show that plants growing in this soil would suffer from an acute deficiency of sulphur and of boron. There was no evidence of any other deficiency that would be of economic importance, but there was some suggestion of an "incipient deficiency" of copper.

Experiment 9

(*a*) *Objective.* To confirm, or deny any effect from copper :—in presence of increasing amounts of N, and in presence or absence of Fe and Mg, on the yield of *Paspalum commersonii* growing in 'cinnamon' sand.

(*b*) *Design and Procedure.* This was a $2^4 \times 4^1$ factorial experiment, using the following nutrients and rates of applications :—

Cu 14 — 14 lb./acre $CuSO_4.5H_2O$
Fe 14 — 14 lb./acre $FeSO_4.7H_2O$
Mg 4 — 4 cwt./acre $MgSO_4.7H_2O$
N 3 — 3 cwt./acre $(NH_4)_2SO_4$
N 6 — 6 cwt./acre $(NH_4)_2SO_4$
and N 9 — 9 cwt./acre $(NH_4)_2SO_4$

There were two replicates of each treatment.

All pots were given a basal dressing of P. (3 cwt./acre $NaH_2PO_4 \cdot 2H_2O$), K. (9 cwt./acre K_2SO_4), and Ca. (15 cwt./acre $CaCO_3$). The $CaCO_3$ was mixed in the upper $1\frac{1}{2}$ inches of soil ; all other nutrients were applied in solution.

The experiment was planted on 4/3/57, and harvested twice, viz.—on 29/4/57 and on 20/5/57. Additional nutrients were applied as follows :—

On 24/3/57 — 7 lb./acre $CuSO_4.5H_2O$ was applied to all pots with added Cu.
Total dose then ≡ 5.4 lb./acre of Cu.

On 19/4/57 — 1, 2 and 4 cwt. NH_4NO_3 was applied to N 3, N 6 and N 9 pots respectively.
Total dose then ≡ 110, 220 and 370 lb/acre of N.

On 16/5/57 — 1, 2 and 4 cwt. NH_4NO_3, was applied to N 3, N 6 and N 9 pots respectively.
Total dose then ≡ 149, 298 and 527 lb./acre of N.

(*c*) *Results.*—Mean yields for the two replicates in two successive harvests are recorded in *Table XIII.*

TABLE XIII. EXPERIMENT 8. *Showing mean yields and level of significance for all treatments affecting the yield of* Paspalum commersonii

Harvest	Treatment			Nil	N 3	N 6	N 9	Effective Treatment	Level of Significance %
(1)	nil	nil	nil	1.64	4.48	6.56	7.94	N	0.1
			Cu	1.71	5.41	6.60	7.88	Mg	1.0
		Fe	nil	1.70	5.31	7.02	7.80		
			Cu	2.01	3.59	7.18	8.49		
Age	Mg	nil	nil	2.30	6.07	8.35	8.73		
56			cu	1.46	7.42	8.73	9.71		
Days		Fe	nil	1.54	6.41	7.05	9.24		
			Cu	2.23	5.17	8.38	9.68		
	Mean			1.82	5.48	7.48	8.68		
(2)	nil	nil	nil	0.34	1.46	2.60	3.70	N	0·1
			Cu	0.32	1.54	2.89	3.64	Cu	5·0
		Fe	nil	0.35	1.42	3.10	3.77		
			Cu	0.35	1.24	2.93	4.59		
Age	Mg	nil	nil	0·49	1.45	2.48	3.08		
77			Cu	0.31	1.65	4.17	3.40		
Days		Fe	nil	0.42	1.54	2.59	3.14		
			Cu	0.49	1.45	3.07	4.04		
	Mean			0.38	1.47	2.96	3.66		

(*d*) *Discussion.* (I) *Nitrogen.* In this experiment nitrogen was applied initially as $(NH_4)_2SO_4$ (doses of 3, 6 and 9 cwt./acre), but on 19/4/57, and again on 16/5/57, additional nitrogen was applied as NH_4NO_3. That was done deliberately, both to avoid any possibility of nitrogen deficiency in pots receiving the highest dosage (see *Experiments 2 and 3, etc.*), and to avoid any complication from late applications of $(NH_4)_2SO_4$.

Those amounts of nitrogen would be far in excess of the requirements for plant growth, and an approximate balance sheet would be as follows :—

	N 0	N 3	N 6	N 9	
Total N applied	0	149	298	527	lb./acre
N removed in plants with 5% protein	24	75	107	126	„
Balance unaccounted for ..	−24	+74	+191	+401	„

In spite of the excess nitrogen applied there was a very marked response to increasing nitrogen dosage (see *Fig. 7* and *Plate 5*) ; with mean yields for N6 and N9 significantly different at the 0·1 per cent. level.

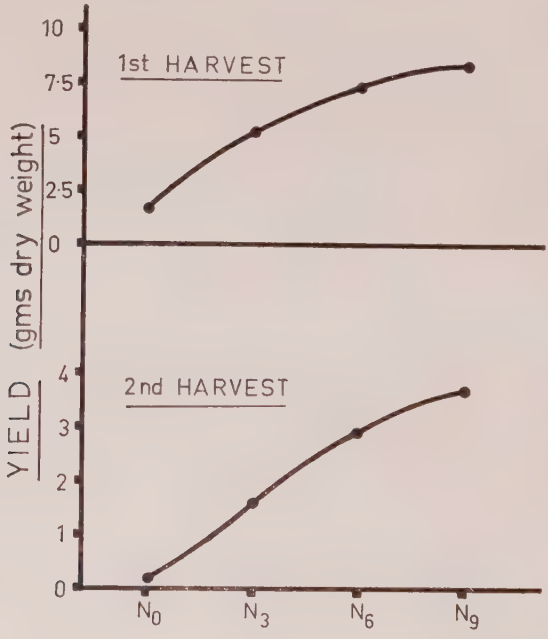


FIG. 7

EXPERIMENT 9. Showing mean yields for plants of *Paspalum commersonii* grown in ' cinnamon sand ', and with increasing amounts of nitrogen *Basal* P, K, Ca, Cu, Fe, Mg.

Since our basic technique would preclude any possibility of loss by leaching, it is difficult to account for any deficiency of available N :—or for reduced yields from N_3 and N_6, unless we assume appreciable losses by diffusion into the atmosphere. For that reason, and in order to avoid similar losses in the field, it is suggested that any nitrogenous fertilizer should be applied in small doses, and at frequent intervals.

(ii) *Copper.* The data from this experiment show that there was a significant response to copper in the second harvest, but the over-all increase in yield did not exceed 15 per cent. On that basis it seems unlikely that a deficiency of copper would be of economic importance. On the other hand, the data do show an ' incipient ' copper deficiency ; which may, in time, become more acute.

(iii) *Magnesium.* In the first harvest there was a significant response to Mg. (restricted to one replicate). However, mean yields were not increased by more than 20 per cent. The effect of magnesium is more clearly portrayed in *Experiment* 12.

(iv) *Iron.* In this experiment Fe. had no significant, or apparent effect on the yield of *Paspalum commersonii* (see also *Experiments 6 and 8*).

Experiments 10, 11 and 12

(*a*) *Objective.* To determine the optimum dosage of Ca, P, K and Mg. ; with particular reference to higher rates of application (cf. Experiments 2 and 3).

(*b*) *Design and Procedure.* These were three simple 4^2 factorial experiments with only one replicate of each treatment. The basal design is shown in *Table XIV*.

In *Experiment 10,* Ca. and K. were applied as $CaCO_3$ (nil, 5, 15 and 20 cwt./acre) and as K_2SO_4 (nil, 6, 9 and 12 cwt./acre) : all pots received a basal dressing of P. (1½ cwt. $NaH_2PO_4.2L_2O$/acre), and Mg. (1 cwt. $MgSO_4.7H_2O$ /acre). In *Experiment* 11, K. and P. were applied as K_2SO_4 (nil, 3, 6 and 9 cwt./acre), and $NaH_2PO_4.2H_2O$ (nil, 1½, 3 and 6 cwt./acre) : all pots received a basal dressing of Mg. (1 cwt. $MgSO_4.7H_2O$/acre), and Ca (20 cwt. $CaCO_3$/ acre). In *Experiment* 12, P. and Mg. were applied as $NaH_2PO_4.2H_2O$ (nil, 3, 6 and 9 cwt./acre), and $MgSO_4.7H_2O$ (nil, 3, 6 and 9 cwt./acre) : all pots received a basal dressing of K. (12 cwt. K_2SO_4/acre), and Ca. (20 cwt. $CaCO_3$ /acre). In all three experiments an additional basal dressing of N. (5 cwt. $(NH_4)_2SO_4$/acre), B. (6 lb. $Na_2B_4O_7.10H_2O$/acre), and Cu. (21 lb. $CuSO_4$ $.5H_2O$/acre) was applied to all pots.

All three experiments were planted on 19/1/57, and harvested 3 times via.—on 6/3/57, 29/4/57, and 20/5/57. All plants were grown from seed and seedlings in excess of two uniform plants per pot were removed as they

appeared. On 19/2/57 the number of plants was reduced to one per pot and those removed (designated 'thinnings') were weighed to give some additional data.

Additional fertilizers were applied as follows :—

On 17/3/57 — 2.5 cwt./acre $(NH_4)_2SO_4$ added to all pots.
Total dose now ≡ 177 lb./acre of N.

On 13/4/57 — 104 lb./acre NH_4NO_3 added to all pots.
Total dose now ≡ 213 lb./acre of N.

On 8/5/57 — 3 cwt./acre NH_4NO_3 added to all pots.
Total dose now ≡ 430 lb./acre of N.

(*c*) *Results.* Cumulative yields for all treatments and for three harvests are recorded in *Table XIV*.

TABLE XIV. *Showing cumulative yields, and level of significance for all treatments affecting the yield of* Paspalum commersonii *in three successive harvests*

Experiment 10

Treatment	K 0	K 6	K 9	K 12	Mean	Effective Treatments	Level of Significance %
Ca 0	1.14	2.67	2.95	3.94	2.67	K	1.0
Ca 5	1.85	14.22	17.74	14.56	12.09	Ca	1.0
Ca 15	3.24	11.02	16.24	19.25	12.44		
Ca 20	2.46	15.12	18.60	19.88	14.01		
Mean	2.17	10.76	13.88	14.41	10.30		

Basal N 5, P 1½, Mg. ½, B 6, Cu 21.

Experiment 11

Treatment	K 0	K 3	K 6	K 9	Mean	Effective Treatments	Level of Significance %
P 0	2.18	9.01	10.92	10.14	8.06	K	0.1
P 1½	3.09	11.74	15.19	18.45	12.12	P	5.0
P 3	3.24	14.48	12.95	15.59	12.48		
P 6	2.63	13.80	14.85	17.56	12.79		
Mean	2.78	12.26	13.48	16.93	11.36		

Basal N 5, Mg 1, Ca 20, B 6, Cu 21.

Experiment 12

Treatment	Mg 0	Mg 3	Mg 6	Mg 9	Mean	Effective Treatments	Level of Significance %
P 0	9.92	9.57	8.87	9.42	9.44	P	5.0
P 3	20.38	20.40	17.62	14.98	18.34		
P 6	15.10	11.23	12.15	16.73	13.80		
P 9	10.69	14.88	18.76	17.91	15.56		
Total	14.02	14.02	14.35	14.76	14.28		

Basal N 5, K 12, Ca 20,B 6, Cu 21.

As with *Experiments 2 and 3*, the data show that there were big responses to K and to Ca, and much smaller responses to P and Mg.

(d) *Discussion*. While these three experiments were separate and could not be combined in any orthogonal pattern, they were nevertheless all planted at the same time and harvested on the same days. The data are, therefore, strictly comparable, and it is possible to compare yields from individual treatments in two, or more experiments. Moreover, where there were no significant differences between treatments it is 'in order' to calculate mean values and to compare them with mean values from another experiment :— provided all treatments received the same, or equivalent basal dressing.

(1) *The Effect of Potassium*. For example, in 'thinnings', and in the first two harvests of *Experiment* 10 there were no significant differences between Ca5, Ca15 and Ca20 ; and in *Experiment* 11 there were no significant differences between P 1½, P 3 and P 6, in any harvest. All pots in *Experiment* 10 received a basal dressing of P 1½, and in *Experiment* 11 all pots received a basal dressing of Ca20. It is therefore 'in order' to combine these data : as shown in *Table XV*. In the third harvest of *Experiment* 10 there were significant differences between Ca5, Ca15, and Ca20, and only the data from Ca20 can be included in this table.

TABLE XV. *Combined data from Experiments 10 and 11, showing individual and mean yields for five rates of K.*

Harvest	Treatment	K 0	K 3	K 6	K 9	K 12
THINNING AGE 31 Days	Ca 5	0.23		0.50	0.61	0.54
	Ca 15	0.13		0.58	0.88	0.88
	Ca 20	0.10		1.02	1.07	0.63
	P 1½	0.15	0.24	0.30	0.55	
	P 3	0.07	0.30	0.17	0.91	
	P 6	0.14	0.38	0.85	0.65	
Mean		**0.14**	**0.31**	**0.57**	**0.78**	**0.68**
(1) Age 46 Days	Ca 5	1.69		4.51	7.01	5.11
	Ca 15	2.29		4.16	7.27	6.21
	Ca 20	2.04		4.93	7.68	4.67
	P 1½	2.02	4.02	5.91	7.60	
	P 3	2.60	6.58	4.44	7.42	
	P 6	2.11	6.33	5.75	7.72	
Mean		**2.12**	**5.64**	**4.95**	**7.45**	**5.33**
(2) Age 100 Days	Ca 5	0.16		6.84	7.62	7.41
	Ca 15	0.95		4.14	5.98	7.46
	Ca 20	0.42		6.85	7.48	7.21
	P 1½	1.05	5.60	6.16	6.99	
	P 3	0.62	6.32	5.63	5.95	
	P 6	0.46	6.26	5.88	5.58	
Mean		**.61**	**6.06**	**5.92**	**6.60**	**7.36**
(3) Age 152 Days	Ca 20	0.00		3.34	3.44	8.00
	P 1½	0.02	2.12	3.12	3.86	
	P 3	0.02	1.58	2.88	3.84	
	P 6	0.06	1.21	3.22	4.26	
Mean		**.02**	**1.64**	**3.15**	**3.85**	—
Mean and s.d. for Four Harvests		1.03 ±0.23	4.45 ±0.73	4.86 ±0.32	6.23 ±0 39	6.58 ±0.48

Finally, the data show that there were no significant differences between K 3 and K 6, or between K 9 and K 12, in either experiment, or in any harvest. Hence, these treatments can be combined to give over-all mean values for K 0, K (3-6) and K (9-12). See *Figs.* 8 *and* 9.

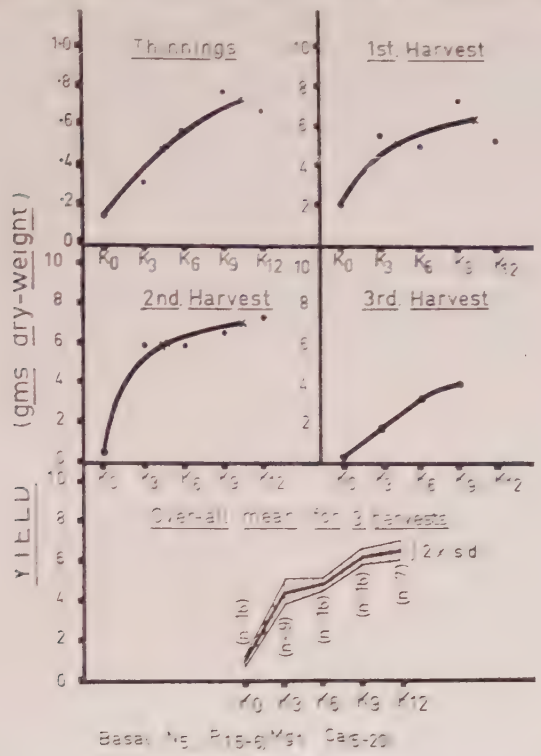


FIG. 8

EXPERIMENTS 10 and 11. Showing the effect of increasing K. K_2SO_4 on the yield of *Paspalum commersonii* in successive harvests. n.b. curves based on mean values for $K_3 + K_6$ and $K_9 + K_{12}$.

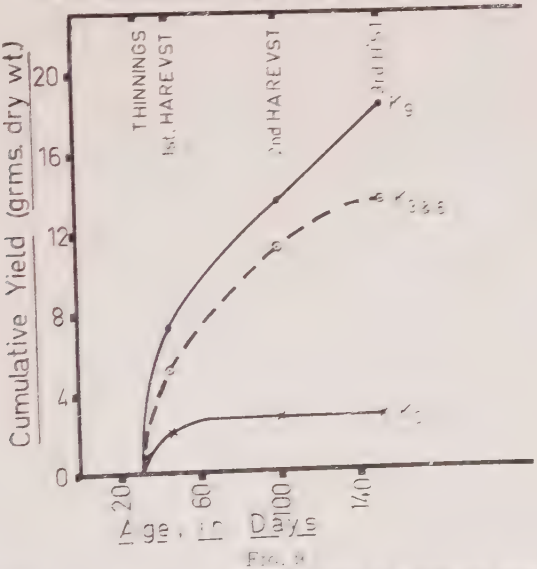


FIG. 9

EXPERIMENTS 10 and 11. Showing cumulative yields of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amount of K. K_2SO_4.

This pattern of responses is shown again in *Plate* 7.

These data show that there was a steady increase in yield from increasing rates of K, up to K9 : but no further increment from still higher dosage (K 12). The greatest difference was between K 0 and K 3, and this pattern of responses was consistent over all three harvests.

(2) *The Effect of Calcium.* The data for Ca. (see *Experiment* 10) show that there was a very big increase in yield from all three rates of application ; while in the second and third harvests, 3 out of the 4 Ca_0 plants were dead. (See *Plate* 6). Relative yields were as follows :—

	Ca 0	Ca 5	Ca 15	Ca 20
Thinnings ..	56	67	87	100
1st Harvest ..	48	95	103	100
2nd Harvest ..	6	100	85	100
3rd Harvest ..	0	54	76	100
Mean ..	27	79	87	100

In ' thinnings ' and in the first two harvests there were no significant differences between doses, and those data suggest that Ca 5 would be sufficient for plant growth. However, in *Experiment* 2 there was a significant difference between Ca 5 and Ca 10 and in the third harvest of this experiment there were significant differences between all four rates of Ca, and a steady increase in yield with increasing dosage. As an initial application (avoiding a rapid ' follow up ') 10 cwt./acre $CaCO_3$ should be near optimal.

(3) *The Effect of Magnesium.* The effect from increasing doses of Mg is recorded in *Experiment* 12. There were no significant differences between mean values for Mg0, 3, 6 and 9. However, in *Experiment* 11 all pots received a basal dressing of Mg 1, and some of that data can be used for direct comparison of yields from plants receiving Mg 0, 1, 3, 6 and 9.

In *Experiment* 11, plants receiving K0, K3 and K6 would not be comparable with those form *Experiment* 12 (basal K 12). But the K9 plants would be directly comparable (this would follow from *Experiment* 10 ; i.e., no significant differences between K9 and K12).* Finally, since there were no significant differences between P1½, 3 and 6 in *Experiment* 11, and none between P6 and P9 in *Experiment* 12 ; it is ' in order ' to combine these data under four rates of P. (see *Table XVI*).

* As additional evidence it can be said that in all three harvests, mean values for K 9 -P (1½-6) in *Experiment* 11 were strictly comparable with those for K (9–12) Ca (5-20) in *Experiment* 10 (differences of 9, 19, 0, and 6 per cent. for thinnings and for 1st, 2nd and 3rd harvests respectively).

TABLE XVI. *Showing cumulative yields and level of significance for all treatments affecting the yield of* Paspalum commersonii *in three successive harvests*

Treatment	Mg 0	Mg 1	Mg 3	Mg 6	Mg 9	Mean	Effective Treatments	Level of Significance %
P 0	9.92	10.14	9.57	8.87	9.42	9.58	P	1.0
P 3	20.38	18.45	20.40	17.62	14.98	18.37		
P 6	15.10	15.59	11.23	12.15	16.73	14.16		
P 9	10.69	17.56	14.88	18.76	17.91	15.96		
Mean	14.02	15.43	14.02	14.35	14.76	14.52		

Basal N 5, K (9-12), Ca 20, B 6, Cu 21.

Mean yields from successive harvests—using this combination of data from two experiments, but excluding P_0 treatments—are shown diagrammatically in *Fig* 10. Cumulative yields are shown in *Fig*. 11.

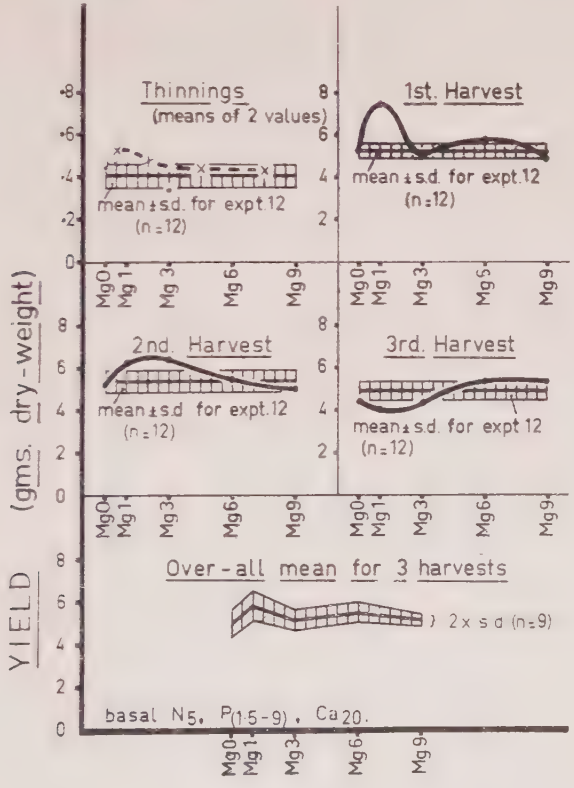


FIG. 10

EXPERIMENTS 11 and 12. Showing the effect of increasing Mg. ($MgSO_4 . 7H_2O$) on the yield of *Paspalum commersonii* in successive harvests.

These data show that there was initially some improvement in the yield of plants receiving the smallest dose of magnesium (Mg 1), and to that extent the data are a confirmation of results from an earlier experiment (see *Experiment* 3). In the second harvest that effect was less pronounced and extended to include the second dose (Mg 3). In the third harvest there was a very small trend towards increasing yields from Mg 6 and Mg 9. There were no significant differences between mean yields for all three harvests.

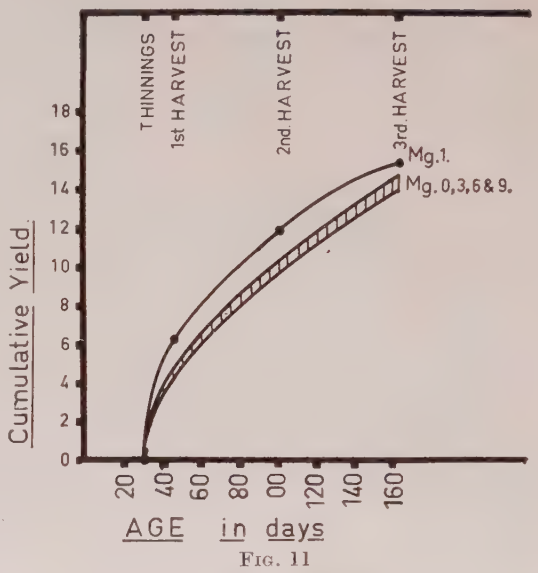


FIG. 11

EXPERIMENTS 11 and 12. Showing cumulative yields of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amounts of Mg ($MgSO_4$. $7H_2O$). *n.b. All values for Mgo,* 3 6 *and* 9 *are included within the shaded band.*

The data suggest that there was some response to small doses of magnesium :— notably in the early stages of growth, and that there may be a continuing demand for that nutrient, which found expression in slightly increased yields from higher doses in subsequent harvests. There was also some visible improvement in the health and colour of those plants (see *Plate* 10). Approximately 1½ cwt./acre $MgSO_4$ would appear to be optimal for any initial dressing.

(4) *The Effect of Phosphorus.* The combined data from *Experiments* 11 *and* 12 (see *Table XVI*) can also be used to measure the effect from increasing doses of P, and mean yields from successive harvests are shown in *Figs.* 12 *and* 13.

The data show that there was a highly significant response to P. (increment of 80 per cent. mean for all doses of P) but very little effect from increasing dosage. Highest yields were recorded from an application of 3 cwt./acre NaH_2PO_4. $2H_2O$.

However, it should be noted that phosphorus was most effective in the early stages of growth (increase of 436 per cent. from P 6. in the yield of 'thinnings'), and somewhat less effective in subsequent harvests (see *Plate* 9). This effect from phosphorus in the early stages of growth appears to be common to all soils that are derived from the 'lateritic gravel'. It is especially important in transplanting, or where any type of grass is to be established from rooted cuttings (see *Plate* 8).

These data are in agreement with results from *Experiment* 3.

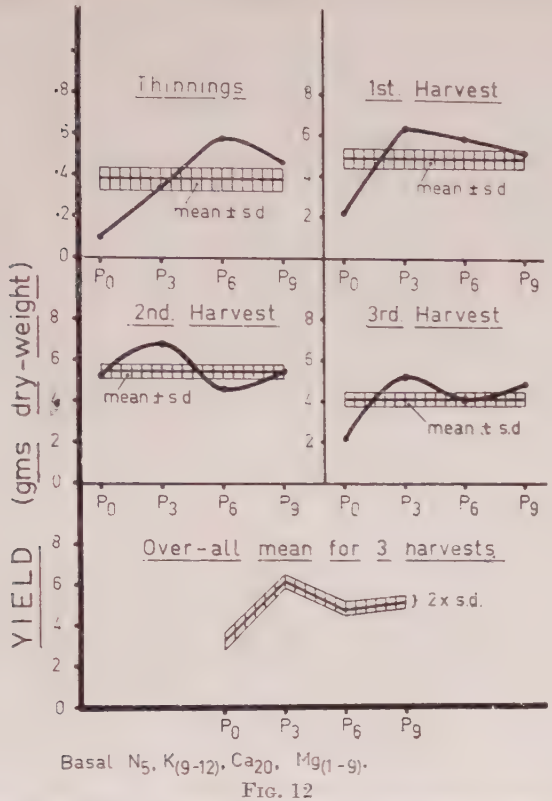


FIG. 12

EXPERIMENTS 11 and 12. Showing the effect of increasing P. ($NaH_2PO_4 . 2H_2O$) on the yield of *Paspalum commersonii* in successive harvests

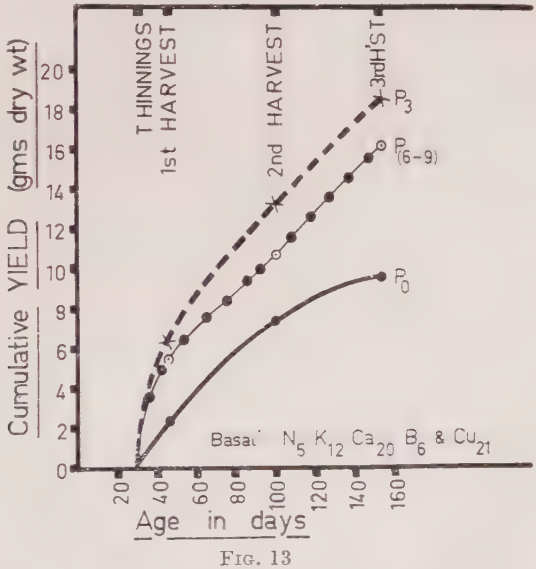


FIG. 13

EXPERIMENTS 11 and 12. Showing cumulative yields of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amounts of P.($NaH_2PO_4 \cdot 2H_2O$)

3. SUMMARY AND CONCLUSIONS

(1) The data from these experiments have shown that plants growing, in the 'cinnamon sand' would suffer from an acute deficiency of potassium of calcium, and of nitrogen. They would also suffer from a deficiency of sulphur, and from lesser deficiencies of phosphorus and magnesium. Leguminous plants would suffer from a deficiency of boron, and there is some evidence of an incipient deficiency of copper.

(2) A peculiar feature of these experiments is that a deficiency of K, Ca, or N—alone—was responsible for the death of a great many plants. This is clearly a soil in which a balanced mixture of nutrients is essential, and one where use of unbalanced fertilizer mixtures could do considerable harm.

(3) *Calcium.* The optimal dose of calcium would appear to be in the order of 10 cwt./acre $CaCO_3$. With less than 5 cwt./acre $CaCO_3$, and in presence of N, P and K, many plants of *Paspalum commersonii* died; while plants of *Phaseolus lathyroides* made very poor growth, and development of root branches was almost entirely suppressed.

(4) *Potassium.* The optimal dose of potassium would appear to be 6 - 9 cwt./acre of K_2SO_4, or equivalent (e.g., 5 - 8 cwt./acre KCl). In absence of K, and with all other nutrients in adequate supply, a majority of plants died. With 3 cwt./acre K_2SO_4 plants of *Paspalum commersonii* grew quite vigorously, but there was a further increase of 15 - 20 per cent. in the mean yield of plants receiving 6 - 9 cwt./acre, and those plants were free of deficiency symptoms.

(5) *Nitrogen.* Approximately 5 cwt./acre $(NH_4)_2SO_4$, (or 3 cwt./acre NH_4NO_3) have been sufficient to meet all requirements for the establishment and early growth of both grass and legume; but this is far short of the requirement for continued growth of a high-yielding and nutritious grass.

With *Paspalum commersonii* 10—15 cwt./acre $(NH_4)_2SO_4$ have been applied in order to maintain satisfactory growth of that species. Use of green manures, or of leguminous plants in general is therefore strongly recommended. Alternatively it is suggested that frequent application of nitrogenous fertilizer in quite small doses would be more effective, least subject to loss by leaching, and more in conformity with the actual demand for plant growth (app. 45 lb./acre of N for $2\frac{1}{2}$ tons dry weight of grass—containing 5 per cent. crude protein—in 6—8 weeks).

Use of ammonium sulphate as a source of nitrogen appears to involve some undesirable effects on plant growth, and ammonium nitrate, or urea—in equivalent N dosage—is recommended.

(6) *Sulphur.* A single dressing of 123 lb. sulphur/acre has proved sufficient for satisfactory growth of grass and legume growing in 2,000 gms. of soil and yielding an equivalent of 2 tons dry weight per acre in 10 weeks That amount of sulphur was responsible for approximately 1,200 per cent. increase in yield.

(7) *Boron.* Under experimental conditions 6 lb./acre of borax ($Na_2B_4O_7$ $10H_2O$) proved sufficient for satisfactory growth of *Medicago sativa*, and cumulative yields were increased by 275 per cent. With 3 lb./acre those yields were reduced by approximately 35 per cent. The yield of a grass (*Paspalum commersonii*) was not affected by boron.

Since these are the only data available, it does not follow that 6 lb./acre would be an optimum rate of application. However, pending further study, heavier doses are not recommended for a sandy soil.

(8) *Phosphorus.* Highest yields were obtained from an application of 3 cwt./acre $NaH_2PO_4.2H_2O$, and there was no evidence of any over-all advantage from still higher rates of application. Phosphorus had most effect in the early stages of growth, and at that time there was some advantage from a higher dosage (6 cwt./acre). This result is in conformity with earlier experiments on the '*Lateritic gravel.*'

(9) *Magnesium.* The data show a definite improvement in yield from applications of 1½ cwt./acre $MgSO_4.7H_2O$, but no improvement in yield from higher doses, up to 9 cwt./acre. At 1½ cwt./acre yields were increased by only 10 per cent., but there is some suggestion that this may be a 'continuing' requirement (i.e., need for repeated small doses), and the physiological importance of magnesium deficiency should not be overlooked.

(10) *Copper.* The data do not provide any completely satisfactory evidence of copper deficiency, and copper does not appear to be a factor of economic importance at the present time.

(11) *Zinc, Manganese, Iron* and *Molybdenum.* There was no evidence of any deficiency of these elements.

(12) Any mixed fertilizer containing N, P, K, Ca, Mg, S and B, in correct proportions should have a highly beneficial effect on plants growing in 'cinnamon sand.' On the other hand, any deviation from the optimum dosage should be avoided, and it is a point of some economic importance that greater amounts of any nutrient (e.g., K. or P) would have little, if any beneficial effect, and would increase the cost of fertilizer.

Suitable mixtures could be formulated in many ways, and should be equally effective. As one example, the authors suggest :—

Mixture A (to be applied before ploughing, or other preparation of seed bed).

	N	P	K	Ca	Mg	B	S	
SAPHOS PHOSPHATE (2.5 cwt./acre)	—	33	—	13	—	—	—	
DOLOMITE (1½ cwt./acre) ..	—	—	—	28	17	—	—	
LIMBUX ($Ca(OH)_2$) 92% (7 cwt./acre) ..	—	—	—	412	—	—	—	
BORAX (6 lb./acre)	—	—	—	—	—	0.8	—	
Mixture B (to be applied when planting).								
AMMONIUM NITRATE (3 cwt./acre) ..	116	—	—	—	—	—	—	
POTASSIUM SULPHATE (6 cwt./acre) ..	—	—	301	—	—	—	124	
	116	33	301	453	17	0.8	124	lb./acre

(13) The amount of this mixture required (1 ton/acre) may involve considerable expenditure, but to the best of our knowledge, that is the minimum dressing required for satisfactory plant growth.

If we assume that coconut trees will have the same, or a similar demand for nutrients, then on coconut estates that expenditure might be reduced by applying this mixture in manure circles ($4\frac{3}{4}$ lb. per tree for a circle with internal and external diameters of 3 ft. 6 ins. and 6 ft. 6 ins. respectively) ; or in wider circles, or strips of greater area, according to the permissible expenditure.

If that were done, then it would be desirable in subsequent years, to use the same mixture in ever-widening circles (or in other strips) until the entire surface of the ground had been so treated.

(14) In our opinion, that expenditure should be regarded as ' capital outlay', and as a pre-requisite for satisfactory growth of plants. It does not follow that the same fertilizer, and expenditure, would be required annually, or bi-annually.

(15) The requirement for maintenance of production, i.e., the type and amount of fertilizer which will be required in subsequent years, has not yet been determined.

4. ACKNOWLEDGMENT

The authors wish to record their appreciation of assistance and advice from Mr. V. Abeywardena (C.R.I. Biometrician), and the careful work done by Mesdames B. Salmond and M. Ginger (Laboratory Assistants). All diagrams and plates were photographed by Mr. B. Hettiarachchi ; the typescript was prepared by Mr. R. de Almeida.

The senior author wishes to express appreciation of the extensive facilities for research afforded by the Coconut Research Institute, and members of the Coconut Research Board.

APPENDIX

The Effect of Nutrients on the Root System of Phaseolus lathyroides growing in ' cinnamon sand '

by

BERYL SALMOND

Plants of *Phaseolus lathyroides* were grown from seed, in six inch, polysterene flower pots, each containing 2,000 gms. of soil. There were twelve pots, subjected to individual treatments in a simple $2^2 \times 3^1$ factorial experiment. There were four treatments using the following combined nutrients :

(1) Major nutrients — (N. P. K.)
(2) Minor nutrients — (Mg., Cu., Zn., Mn., Fe., B., Mo.)
(3) $Ca(OH)_2$ = 4.0 cwt. Ca per acre.
(4) $CaCO_3$ = 4.0 cwt. Ca per acre.

The seed was sown on 12.5.56, and the plants were harvested twice, viz. on 4.7.56 and 11.8.56. At harvesting the plants were cut back to a point approximately $\frac{1}{4}$ inch above the third node in the main stem.

After the second harvest, soil and roots from all twelve pots were removed *en masse*, and the soil carefully washed away in running water. The root system of each plant was then suspended in a large beaker full of clean water. Twenty-four hours later they were mapped (see Fig. 2) and appropriate measurements recorded. (See *Table XVII.*)

TABLE XVII. EXPERIMENT 1. *Data showing depth of penetration and general vigour of root systems of* Phaseolus lathyroides *grown in 'cinnamon sand.'*

Treatment	Nil	Minors	Majors	Minors + Majors	Mean
			DEPTH OF ROOT SYSTEMS		
Nil	14.1 cms.	11.0 cms.	7.5 cms.	13.0 cms.	11.5
$Ca(OH)_2$	12.0 cms.	9.0 cms.	11.0 cms.	16.0 cms.	12.5
$CaCO_3$	17.0 cms.	9.0 cms.	11.0 cms.	12.5 cms.	12.5
Mean	**14.0 cms**	**10.0 cms.**	**10.0 cms.**	**14.0 cms**	—
			LENGTH OF LATERAL ROOTS		
Nil	1·5–20·0 cms.	13.0 cms.	12.0 cms.	2.0–18 cms.	16.0
$Ca(OH)_2$	3·0–12·0 cms.	10.0 cms.	2·0–21·0 cms.	17.0 cms.	15.0
$CaCO_3$	1·0–20·0 cms.	9.0 cms.	6.0 cms.	16.0 cms.	13.0
Mean	**17.0 cms.**	**11.0 cms.**	**13.0 cms.**	**17.0 cms.**	—
			DIAMETER OF TAPROOTS		
Nil	3.0 mm	3.0 mm	4.0 mm	4.0 mm	3.5
$Ca(OH)_2$	2.0 mm	2.0 mm	—	—	3.0
$CaCO_3$	3.0 mm	2.0 mm	6.0 mm	6.0 mm	4.0
Mean	**3.0 mm**	**2.0 mm**	**5.0 mm**	**5.0 mm**	—
			DIAMETER OF LATERAL ROOTS		
Nil	1.0 mm	0.5 mm	—	0.5–1.0 mm	0.8
$Ca(OH)_2$	1.0–1.5 mm	0.5 mm	1.5–3.0 mm	0.5–3.0 mm	2.0
$CaCO_3$	1.0–1.5 mm	0.5–1.0 mm	1.0–1.5 mm	0.5–3.0 mm	1.8
Mean	**1.3 mm**	**0.7 mm**	**1.5 mm**	**2.3 mm**	—

The effect of nutrients may be summarized as follows :—

(1) *Nil.* Where no nutrients had been applied, the root system of *Phaseolus lathyroides* was very well developed with a prominent tap-root and long laterals. All roots appeared to be healthy and vigorous.

(2) *Calcium.* Where calcium was applied together with major nutrients (N.P.K.), there was a definite increase in the number and diameter of lateral roots, and there was some differential effect from the different forms of calcium. In the $CaCO_3$ treatments root systems had a definite tap-root and associated laterals, but in the $Ca(OH)_2$ treatments the tap-root was suppressed and replaced by a number of stout laterals. In absence of NPK, calcium appeared to have very little effect on root growth.

(3) *Minors.* The main effect from minor nutrients, alone and in combination with calcium, was a tendency to some reduction in the size and number of lateral roots. However, there was some increase in the number of very fine rootlets. On the whole these root systems seemed to be somewhat smaller than those of untreated plants.

(4) *Majors.* In the absence of calcium, addition of N, P and K appeared to have a very adverse effect on root growth in this plant, and the root system comprised no more than a large tap-root and one or two laterals ; there were no fine rootlets. In presence of calcium there was some improvement, notably in a development of short laterals of the second and third order. There was also a differential effect from the two forms of calcium, (see 2 above).

(5) *Minors + Majors.* This root system showed considerable improvement on those developed in presence of majors alone. It was, however, somewhat smaller than that of untreated plants.

(6) *Minors + Majors + Calcium.* In presence of all three nutrients the root system of Phaseolus lathyroides was very well developed, with long, freely branched laterals and numerous fine rootlets. Here again there was some differential effect from the two forms of calcium, and plants treated with $Ca(OH)_2$ had no clearly defined tap-root.

(7) *Nodulation.* The development of root nodules was more or less restricted to those plants that had received calcium, and/or 'majors minors'. In the absence of N, P and K there were very few nodules, and in the absence of minors a somewhat better development extending to the lateral roots. In presence of all three (majors + minors + calcium) nodulation was very satisfactory, with large numbers of well developed nodules close to the soil surface and attached mainly to the lateral branches.

Plate 1. EXPERIMENT 1. *2nd Harvest.* Plants of *Paspalum commersonii* and of *Phaseolus lathyroides* grown in cinnamon sand with and without calcium ($CaCO_3$ and $Ca(OH)_2$), major nutrients (N, P and K) and minor nutrients (Mg, Cu, Zn, Mn, Fe, B and Mo).

Plate 2. EXPERIMENT 2. *3rd Harvest.* Plants of *Paspalum commersonii* grown in ' cinnamon sand ', and with increasing amounts of calcium ($CaCO_3$). *Basal* N, P, K and Mg.

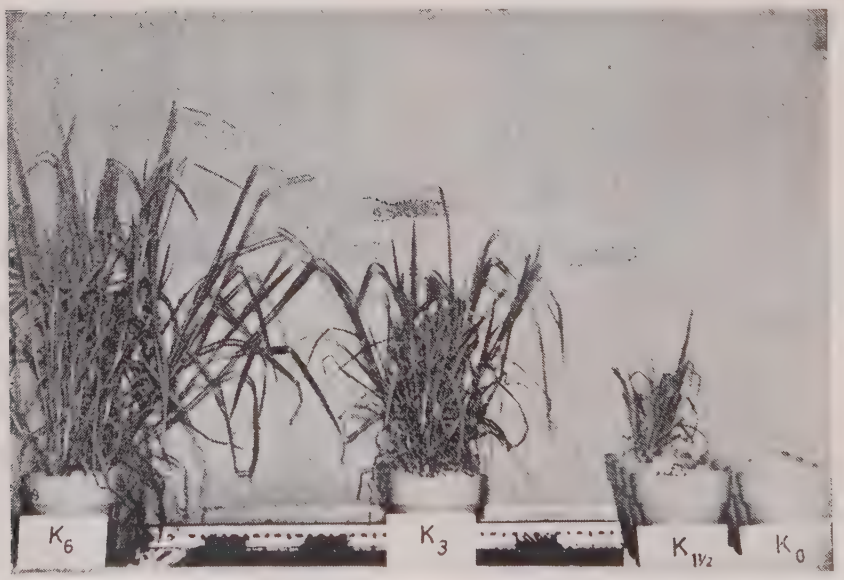


Plate 3. EXPERIMENT 3. *3rd Harvest.* Plants of *Paspalum commersonii* grown in ' cinnamon sand ' and with increasing amount of potassium (K_2SO_4). *Basal* N, P, Ca and Mg.

Plate 4. EXPERIMENT 5. *Regrowth after 1st Harvest.* Plants of *Phaseolus lathyroides* grown in ' cinnamon sand ', with and without sulphur in various combinations.

Plate 5. EXPERIMENT 9. *2nd Harvest.* Plants of *Paspalum commersonii* grown in ' cinnamon sand ', and with increasing amounts of nitrogen (NH_4NO_3). *Basal* P, K, Ca, Mg, B, Cu and Fe.

Plate 6. EXPERIMENT 10. *2nd Harvest.* Plants of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amounts of calcium ($CaCO_3$). *Basal* N, P, K, Mg, S, B and Cu.

Plate 7. EXPERIMENT 10. *2nd Harvest.* Plants of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amount of potassium (K_2SO_4). *Basal* N, P, Ca, Mg, S, B and Cu.

Plate 8. Seedlings of *Paspalum commersonii* transplanted to ' cinnamon sand ', and grown with and without phosphorus (NaH_2PO_4. $2H_2O$).

Plate 9. Experiment 12. *2nd Harvest.* Plants of *Paspalum commersonii* grown in ' cinnamon sand ', and with increasing amounts of *Phosphorus* (NaH_2PO_4. $2H_2O$). *Basal* N, P. K, Ca, B and Cu.

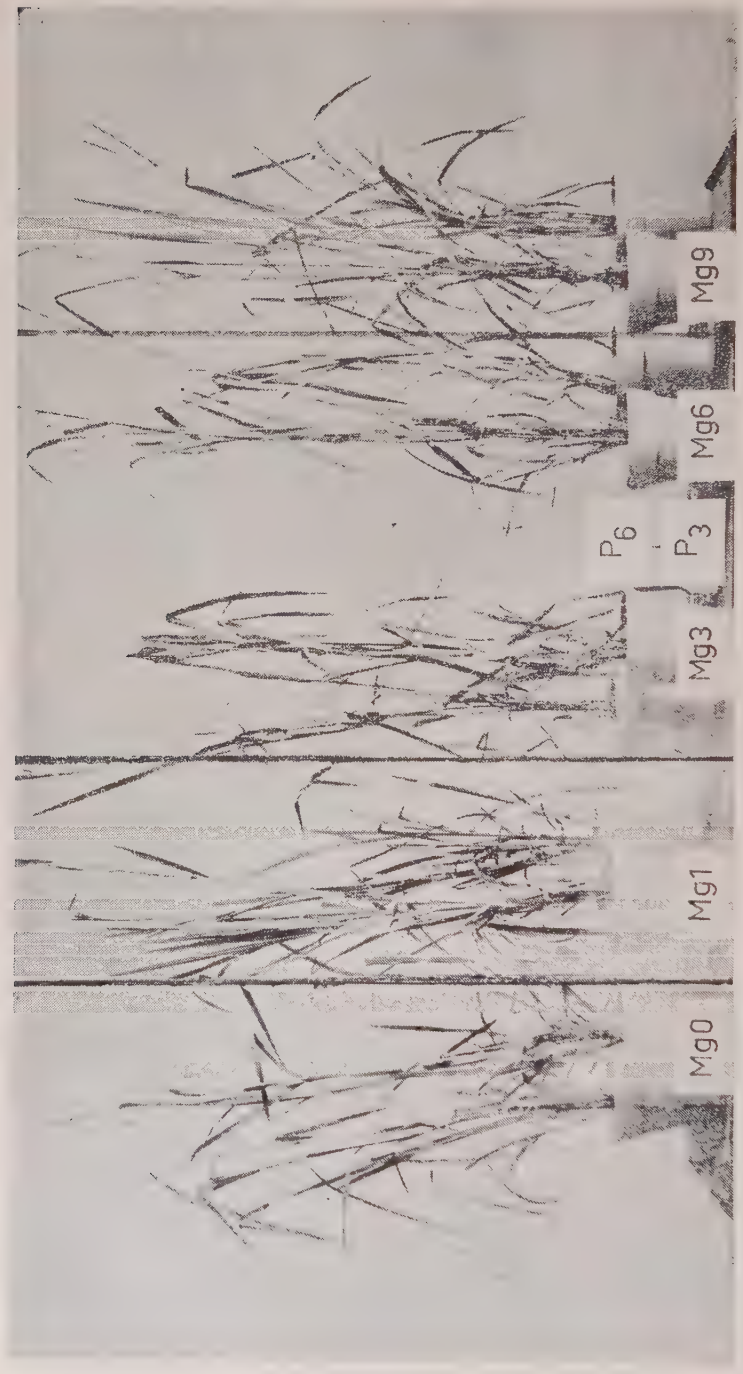


Plate 10. Experiments 11 and 12. *2nd. Harvest.* Plants of *Paspalum commersonii* grown in 'cinnamon sand', and with increasing amounts of magnesium ($MgSO_4.7H_2O$). *Basal* N, K, Ca, B and Cu.

INVESTIGATIONS ON THE CHILLI LEAF CURL COMPLEX AND ITS CONTROL

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(Ceylon Department of Agriculture)

INTRODUCTION AND REVIEW OF LITERATURE

THE CHILLI CROP in Ceylon is subjected to attack by several pests and diseases among which are mites, thrips and virus diseases (Peiris 1953). This country is however not alone in having to contend with chilli pests and diseases which form a major limiting factor to larger chilli harvests.

In Spain, Sardina (1941) has described a virus disease of chilli peppers (chilies) involving especially a dark green mottling of the leaves and a crinkling of the leaf surfaces and transmissible by the aphid *Myzus persicae*. In Bulgaria, Kovachevsky (1943 and 1948) has described a series of virus diseases affecting chilli pepper among which that caused by the cucumber mosaic virus transmitted by the aphids, *Aphis gossypii* and *Myzus persicae* is most serious. Similar diseases of chilli pepper have been noted in Italy. In Puerto Rico a virus disease causing the mottling of foliage, stunting of plants and malformation of fruits, transmitted by *Myzus persicae* has been described by Roque (1943). In the Caucasus region of Russia a disease involving chlorosis along the edges of the apical leaves, yellowish stains between veins, reduction of leaf surfaces which become boat shaped and shortening of internodes, transmitted by the coccid bug *Hyalesthes obsoletus* has been described by Sukhov (1951). Leaf curl virus diseases of chilli transmitted by *Myzus persicae* and *Aphis gossypii* in Java have been described by Van Schewen (1950). In U. S. A. several virus diseases are recorded as affecting chilli peppers (Simmons 1957 ; Anderson *et al* 1957). In India the leaf curl virus of chilli is widespread and is responsible for considerable losses of this crop. It is transmitted by the whitefly *Bemisia tabaci*. In Ceylon three virus diseases of chilli have been described by Peiris (1953) while the whitefly *Bemisia inconspicua* and the aphid *Aphis gossypii* have been proved as vectors of two of these diseases by Fernando (1953).

Virus diseases have not alone been responsible for losses to the chilli crop. The thrips *Scirtothrips dorsalis* was recorded by Cherian (1936) as being a major pest of chilli in India causing leaf curl. An unidentified thrips was recorded by Johnpulle (1939) as causing leaf-curl of chilli in Ceylon. This thrips has recently been identified as

Scirtothrips dorsalis. The mite *Hemitarsonemus* (*Tarsonemus*) *latus* was recorded by Hambleton (1938) as causing chilli leaf curl in Brazil and by Mackie *et al* (1939) as causing leaf curl of chilli peppers in Los Angeles, U. S. A. The same species of mite was recorded in South Africa and the Belgian Congo as causing injury to chilli leaves by Lavoipierre (1941) and Vrydagh (1942) respectively. Peiris (1944) described a leaf malformation of chilli caused by an unidentified mite. This mite has recently been identified as *Hemitarsonemus latus*.

While a wealth of information is available in the literature on the nature of pests and diseases of chilli, little practical results have been achieved on the actual control of chilli virus diseases. Kenneth Smith (1957) records no known method of control of the tobacco leaf curl disease, of which chilli leaf curl is a strain, by the control of insect vectors. Simmons (1957) has reported on the value of insecticides and physical barriers on the control of a mosaic disease of chilli without encouraging results. However in some instances insecticides have proved to be of definite value in the control of certain plant virus diseases by achieving vector control (Broadbent 1957).

The work to be reported in this paper represents studies conducted by the authors during the past several years. While these studies are far from complete it is felt that some contribution to the knowledge on this subject has been made and that a detailed review of the work done would provide a basis for the orientation of any future research programmes on this problem.

THE NATURE OF INSECT AND MITE DAMAGE AND DISEASES IN CHILLI IN CEYLON

Peiris (1953) has described the various factors causing leaf curl and other pathological conditions in the chilli plant. These conditions are briefly reviewed here and the additional information obtained since 1953 is presented.

Five factors have been mentioned by Peiris (1953) as being responsible for chilli leaf malformations. These are (*a*) mites, (*b*) thrips, (*c*) the vein-clearing virus disease, (*d*) the leaf mottle virus disease, and (*e*) the tobacco mosaic virus. The thrips and mites induce leaf curl by the mechanical injury caused to the leaf surface and perhaps also by a toxic component introduced by these organisms with the saliva into the leaf during feeding. The species of mite responsible for chilli leaf curl has recently been identified as *Hemitarsonemus latus*. This mite is notorious in many parts of the world for causing leaf curl of chillies and has an extremely wide host range. It causes leaf malformations in all its host plants and has recently been found to cause leaf malformation and stunting in papaw plants.

The thrips involved in the leaf curl of chilli has recently been identified as *Scirtothrips dorsalis*. Feeding by this insect is mainly on the young leaves as soon as they appear and on the upper surface. This same thrips has been recorded on cacao where again feeding is predominantly on the upper surface, resulting in an intervenal buckling of the leaf surface similar to that induced on chilli.

The leaf malformations caused by the vein clearing virus and the leaf mottle virus have been transmitted by the white-fly *Bemisia inconspicua* and the aphid *Aphis gossypii* respectively (Fernando 1953). Details of these transmission experiments are given below.

In addition to the three virus diseases already described by Peiris (1953), what might well prove to be two other virus diseases of chilli, have been recognized. These are the little leaf of chilli and a mosaic of *Capsicum annum*.

Little Leaf of Chilli. This malady has recently become increasingly common in the Jaffna, Puttalam and Vavuniya districts. It makes its appearance towards the latter stages of the life of the chilli crop. The leaves in this case are progressively reduced in size until the lamina as such is almost completely suppressed. In this condition the leaf is proportionately thickened, brittle and reduced up to less than 0.5 centimeter in length in extreme cases. In the most acute condition only the branches of the plant are apparent from a short distance, the apical branches presenting a skeletonized appearance. The exact nature and causal basis of this condition in chilli are not yet understood.

Mosaic of Capsicum annum. Symptoms strongly suggesting a new virus disease have recently been observed in plants of *Capsicum annum*. In seedlings the symptoms consisted of a mosaic of yellow white and green areas on the leaves with no leaf distortion. Most of the symptoms may disappear as the plants reach maturity when the presence of the disease is recognizable by a very faint yellow mottling of the veins. This disease does not appear to cause sufficient damage to the crop to warrant its being regarded as one of major economic importance.

POSSIBLE RELATIONSHIP OF EELWORMS, ROOT DISEASES OR OTHER SOIL-BORNE FACTOR TO CHILLI MALADIES

The possibility that a soil-borne factor such as eelworms or root diseases was responsible for chilli leaf curl had been suggested repeatedly in Jaffna. Experiments were therefore carried out to elucidate this aspect of the problem. Eight chilli seedlings were enclosed

in spacious muslin-covered insect proof cages in the field chilli plots immediately after transplanting. At the close of the season the caged plants were examined for signs of disease and in no case had any symptoms of disease appeared although the non-caged plants growing within two feet of the caged plants showed symptoms of all the virus diseases of chilli and of "little leaf." This experiment proved beyond doubt that the chilli diseases under investigation were not caused by a soil-borne factor such as eelworms or root diseases but required a free-moving animal vector for transmission.

INSECT TRANSMISSION OF CHILLI VIRUS DISEASES

A survey of the insect and other fauna on the chilli crop, especially those which were most likely to be vectors of virus diseases, showed the presence of the aphid *Aphis gossypii,* the thrips *Scirtothrips dorsalis,* the whitefly *Bemisia inconspicua* and the mite *Hemitarsonemus latus.* Each of these organisms was tested for its possible involvement in the transmission of chilli diseases.

Sources of Insects and Mites for Transmission Studies. The thrips *S. dorsalis* was collected from diseased plants showing symptoms of either the vein clearing virus or the leaf mottle virus in the field. The growing portions of such plants having thrips were brought to the laboratory and the insects were dislodged on to a sheet of black paper by shaking infested sections of the plants violently over it. The thrips were then transferred on to test plants by way of a moist camel hair brush.

Cultures of the aphid *A. gossypii* were easily maintained in the laboratory. A few gravid parthenogenetic females were collected from the field and placed on virus-diseased plants grown inside insect-proof cages of the type illustrated in Plate I. Disease free cultures of *A. gossypii* were maintained similarly but the parents of such colonies consisted of individuals picked up at birth from the genital orifice of parthenogenetic females before these young could feed. The nymphs were placed on healthy chilli plants grown under insect-proof cages.

The mite *H. latus* was obtained for transmission studies from plants showing virus-disease symptoms. Infestation of healthy plants with such mites was done by placing a mite-infested leaf from the diseased plant at the terminal growing point of the test plant.

Cultures of the white fly *B. inconspicua* were maintained in the laboratory on virus diseased chilli plants enclosed in insect-proof cages (Plate I.) A diseased plant from the field was first potted and enclosed in the case. White flies collected in the field were then introduced on to these plants. Build-up of the culture was found to be extremely

PLATE I— Insect-proof cage used in insect transmission studies or for maintaining insect cultures in chilli plants.

rapid except during spells of wet weather when mortality in the colony was especially high due to a fungus disease. Small cultures of the whitefly were raised in leaf cages as illustrated in Plate 2.

All efforts at producing a disease-free colony of white flies were unsuccessful. White flies were cultured on kapok (*Eriodendron anfractuosum*) seedlings and on the weed *Acaranthes aspara* for several generations and were still found to be viriliferous. Efforts at collecting hatching nymphs of the white fly and placing them on healthy plants failed, because the nymphs did not survive this treatment.

PLATE 2—Leaf cage used for maintaining white fly cultures and for isolating insects in disease transmission experiments.

Insect Transmission of Leaf Mottle Virus Disease of Chilli. Infestation of the mite *H. latus,* the thrips *S. dorsalais* and white fly *B. inconspicua,* raised on infected leaf mottle chilli plants, onto separate one month old chilli seedlings (raised under insect-proof conditions before and after the test infestations) produced no symptoms of the leaf mottle virus even though feeding by these organisms was very extensive. Those seedlings which were infested with white flies however developed the vein-clearing virus disease, which was probably masked by leaf mottle virus symptoms in the plant upon which the white flies were raised. The month-old seedlings which were infested with *Aphis gossypii* ranging from 5 to 10 and 15 aphids per plant however

developed symptoms of the leaf mottle virus disease. Initial symptoms appeared in about 18 days in the form of an abnormal elongation of the hardening leaves in proportion to the width of the leaf. A few consecutive veins on such leaves followed an irregular meandering course on the leaves after approaching each other. By about the 24th day after infection feeding commenced parts of the leaf surface developed circular or oval blisterlike appearance and these areas became deep green in colour giving the typical mottles characteristic of this disease. *A. gossypii* was therefore established as the vector of this disease. No experiments were conducted to assess the persistency of the virus in the aphid.

Insect Transmission of the Vein-clearing Virus Disease of Chilli. Test infestations of month-old chilli seedlings with *H. latus*, *S. dorsalis* and *A. gossypii* taken from plants having the vein-clearing virus disease showed that these organisms were incapable of transmitting the vein-clearing virus disease.

One month old chilli seedlings, grown under insect-proof conditions in individual 3″ pots, were infested with white flies raised on vein-clearing virus diseased chilli plants. Infestation was done at the rate of 5, 10 and 15 white flies per plant. Infection feeding was ensured by placing over each plant a section of 2″ diameter glass tubing with one end closed with muslin cloth and other end embedded in the soil around each plant, and then introducing the white flies from the lower end of the glass cylinder. The restriction of space around each test seedling by this method of caging of the plants resulted in rapid settling and infection feeding by the white flies. After 3 days the plants were sprayed with malathion to destroy the white flies and the spraying, especially of the undersides of the leaves, was repeated one week later to kill out hatched larvae of white flies.

On about the eighth day after infection feeding the tender leaves at the growing point began to show symptoms of the vein-clearing virus disease. The areas immediately bordering the veins showed a yellowish tinge against the light green of the intervenal regions of the leaf. When viewed in transmitted light the transparency of the veins was incipient but distinct in the young flush. As the leaf hardened it became boat shaped with the leaf margins curling upwards and the yellowing along the veins becoming more distinct. Subsequently the developing internodes became progressively shortened while the leaf size became proportionately reduced. By about the twelfth to the eighteenth day after infection feeding the leaf symptoms of the vein-clearing virus disease became clearly marked.

Further experiments were carried out to determine the minimum number of white flies and duration of feeding on chilli plants required to induce virus infection of the test plants. In these experiments the infective white flies were first temporarily deactivated by cooling to a temperature of about 5°C or by carbon dioxide anaesthesia. Recovery from cooling was slow but recovery for carbon dioxide anaesthesia was rapid so that deactivation of insects by cooling was preferred. The deactivated insects were transferred on to leaf cages (Plate 2 and 3) at the rate of 1, 5 or 10 white flies per leaf cage per chilli seedling which was about 1½ months old. Feeding was permitted for 48 hours and the white flies were removed from the leaf cages. Symptoms of the vein-clearing virus disease appeared in all the test plants infested with 5 white flies per plant. In the experiment with 1 white fly per

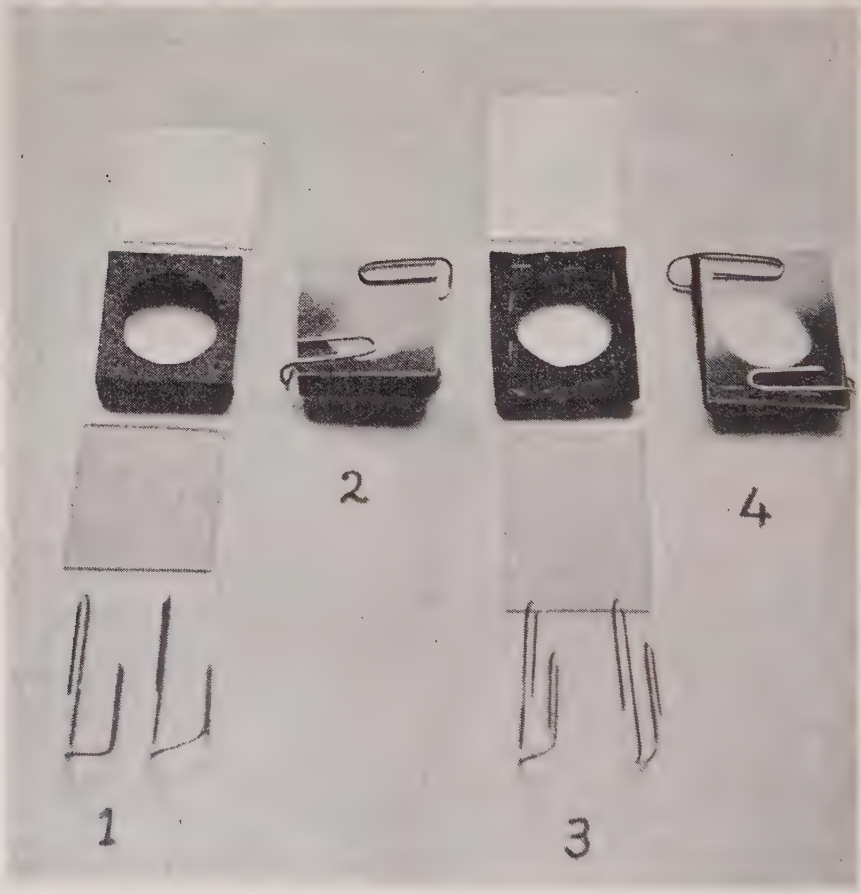

PLATE 3 — Components of leaf cages used in insect culture or disease transmission experiments.

plant, survival of the insects after 48 hours was good but where 10 white flies were used per plant, survival after 48 hours was extremely poor.

This series of experiments with the white fly, *B. inconspicua*, proved that this insect was a very efficient vector of the vein-clearing virus disease.

ALTERNATE HOST PLANTS OF VEIN CLEARING VIRUS OF CHILLI

Production of Virus free Strain of B. inconspicua. As a preliminary to the study of the alternate host plants of the vein-clearing virus disease efforts were made to produce a virus free strain of *B. inconspicua*. If such a strain of white flies became available they could be fed upon a series of wild or cultivated plants growing in the neighbourhood of chilli cultivations and then transferred on to healthy chilli seedlings for testing of viriliferousness. Such a method would simplify the solution of the problem of alternate hosts of the chilli vein-clearing virus disease.

White flies were cultured on healthy kapok (*Eriodendron anfractuosum*) sweet potato (*Ipomea batatas*) and a weed *Acharanthes aspera* for two generations. No symptoms of any disease appeared upon any of these plants but infestation of such white flies on to healthy chilli seedlings showed that they were still viriliferous as the test seedlings all developed the vein-clearing virus disease. While *B. inconspicua* is normally not found on kapok in nature, it fed and oviposited normally when caged on these plants. They proved to be symptomless hosts of the vein-clearing virus disease. Attempts at producing a strain of virus free white flies by transferring on to healthy chilli plants the first instar nymphs from the leaves as soon as they hatched out and before they fed, failed because of mortality of the transferred nymphs for unknown causes.

Tests for Transmission of Vein-clearing Virus of Chilli to Other Plants. Among cultivated crops it appeared most likely that the other *Solanaceae* such as tomato, brinjal and tobacco would very likely be alternate hosts of at least some of the chilli virus diseases. Using seedlings of tomato, brinjal (about 1½ months old) and tobacco grown under insect-proof conditions, infection tests were carried out with white flies *B. inconspicua* raised on vein-clearing virus diseased chilli plants. Fifteen viriliferous white flies were used for each test seedling. After 3 days feeding the white flies were destroyed by a spray of malathion and the plants grown under insect-proof conditions.

No symptoms of any disease developed on the test brinjal seedlings In the case of the tomato seedlings, on the other hand, on about the twelth day after feeding by white flies a retardation in growth rate was observed. By about the eighteenth day after infection feeding the typical symptoms of tomato leafcurl with a sequence of symptom appearance identical to that of the vein-clearing virus on chilli developed in the test tomato seedlings.

In the test tobacco seedlings about 15 days after infection feeding by the white flies the leaf edges were noted to curl downwards and vein-clearing was marked. There was also a slight tendency for some of the veins to assume an abnormal meandering course on the leaves. No enations on the veins developed. These symptoms strongly resemble those described by Thung (1932) for the transparent kroepoek strain of the leaf curl virus of tobacco. The vein-clearing virus disease of chilii may on the basis of these tests be identical with the transparent kroepoek strain of tobacco leaf curl virus.

Ageratum conizoides and *Gynura crepidioides* are two common weeds around chilli plantings showing symptoms of virus diseases. The virus disease of *Ageratum* has been transmitted to tobacco (Godd & Loos 1941). As no virus-free strain of *B. inconspicua* was available it was not possible to attempt to transmit by insect vector the *Ageratum* virus to chilli. However tests with vein-clearing virus infective *B. inconspicua* infested on healthy seedlings of *Ageratum* and *Gynura* plants proved that the vein-clearing virus of chilli did not evoke any virus symptom expression in the test plants. The experiment however does not exclude the possibility that these two weeds are symptomless hosts of the vein-clearing virus disease of chilli. This could only be elucidated if a disease-free strain of white flies was available.

TESTS FOR VIRUS RESISTANCE IN CHILLI VARIETIES BY INSECT TRANSMISSION TECHNIQUES

In a series of preliminary experiments involving 6 varieties of chilli it was found possible to screen large numbers of chilli plants by the use of infective white flies for susceptibility or resistance to the vein-clearing virus disease. Seedlings of the local chilli varieties (*a*) Iddaikadu, (*b*) Thokaiyam Puloly, (*c*) Neelam Suthumalay, (*d*) Local Myliddy, (*e*) Black Mathakal, and (*f*) Local Tinnevely were tested. Eight to ten infective white flies were used per month-old chilli seedling confined in a section of glass tubing of 2-inch

diameter closed at one end with muslin cloth. In this experiment 12 to 15 days after infective feeding 60 per cent. to 70 per cent. of the test seedlings developed leaf curl virus disease symptoms. This experiment was not pursued further but it is hoped to use this technique for rapid selection of plants showing resistance to the vein-clearing virus disease.

FACTORS RESPONSIBLE FOR HIGH INCIDENCE OF CHILLI DISEASES IN JAFFNA PENINSULA

The factors influencing the high incidence of leaf curl of chilli in the Jaffna peninsula have been under careful observation. It has been noted that (*a*) the cultivation throughout the year of other *Solanaceae* which were proved alternate hosts of the virus diseases of chilli and (*b*) the scant attention paid by cultivators to clean weeding in and around chilli cultivations were two main contributory factors in this respect.

Tomato and tobacco are proved alternate hosts of chilli pests and diseases. The cultivation of these *Solanaceae* together with chilli season after season without a break permits an unchecked build-up of disease vector populations. Furthermore the practice of allowing crop residues to remain on the field until preparation for the next season's plantings in the hope of extending the harvest has encouraged the carryover of chilli pests and diseases from season to season.

Wolf *et al* (1949) lists sixty-three species of plants from fourteen families susceptible to tobacco leaf curl virus. Chilli leaf curl represents one of the strains of this virus. The wild host range of this virus is therefore very wide but clean weeding in and around chilli plots in Jaffna is almost completely neglected. These weeds therefore provide a reservoir of primary virus infection within the chilli plots themselves.

The possibility that sandy soils had an influence on the incidence of chilli diseases had been mooted for some time. Careful observations made of the incidence of weeds, insect vectors of chilli diseases and virus diseases of chilli in sandy tracts, however, showed that primary infection with virus diseases was merely delayed on account of the scarcity of weeds and other vegetation upon which insect pests and virus vectors could survive under such conditions. Once primary infection occurs secondary infection becomes extensive within a short time.

INSECTICIDAL CONTROL OF CHILLI PESTS AND DISEASES

Three species of insects and a mite have been demonstrated to be either directly or indirectly (as vectors of virus) responsible for damage to the chilli crop. Both these types of damage could be controlled if the organisms involved are controlled in time. A series of insecticidal trials were therefore carried out with this end in view.

The first insecticidal trial for the control of chilli leaf curl was carried out at Peradeniya. Spraying was done at 20 to 60 gallons of spray per acre with a knapsack-type sprayer equipped with hollow cone nozzles. Spraying was repeated at weekly intervals. Table I gives the details and results of this trial. It is apparent from these results that DDT emulsion, sulphur wettable powder and toxaphene emulsion spray treatments gave complete control of the mite *Hemitarsonemus latus*, and also together with Toxaphene wettable powder spray and the BHC-Sulphur dust mixture gave good control of the aphid *Aphis gossypii*. This data also suggests that the DDT-Sulphur and BHC-Sulphur dust combinations gave some measure of leaf curl control caused by virus disease.

The second insecticidal trial was conducted at the Tinnevely Farm, Jaffna. The treatments consisted of toxaphone and DDT emulsions and sulphur wettable powder at two concentrations, and applied either at fortnightly or monthly intervals. This trial could not be carried through to the end of the season but Table 2 gives the results as obtained after $2\frac{1}{2}$ months. Inspection of the crop at the end of the season showed complete infestation with leaf curl. The data showed that all the insecticidal treatments gave good control of all the various types of leaf curl. The data represented as "recovered" indicates the efficacy of these treatments in controlling mite and thrip-caused leaf curl.

The availability of a series of new organophosphorus systemic and contact insecticides, and reports from the field that the earlier recommended measures were not achieving the desired control of leaf curl necessitated an assessment of these chemicals for the control of chilli leaf curl. The insecticides parathion diazinon, malathion, metasystox and ekatin were tested as general leaf sprays while metasystox and ekatin were tested solely as systemic insecticides by root treatment of plants. The systemic insecticidal trial gave no data as leaf curl incidence was very low in the test plots. The general leaf sprayings were done at one of two concentrations and at one of two frequencies in the test plots. Table 3 gives the results of this trial which included data on incidence of thrips, mites, vein-clearing virus, leaf mottle

TABLE I -Effects of 7 Weekly Sprayings on the Control of Chilli Mites, Aphids and Leaf curl

Insecticidal Treatment	% Mite Infestation		% Aphid Infestation		% Leaf Curl Incidence		Average % Pest and Disease infestation in two Replications		
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Mites	Aphids	Leaf Curl
DDT 25% E.C. 3·5 fl. oz. in 1 gal. water	0	0	0	0	47·4	36·9	0	0	42
DDT 5% Sulphur dusts in ratio 1 : 1	80	60	100	0	28·1	9·3	70	50	18·7
Sulphur 50% W.W.P. 1 oz. of in 1¼ gal.	0	0	60	0	20·3	41·6	0	30	30·9
BHC 20% E.C. 1 fl. oz. in 6½ gals. water	60	100	100	0	53·7	45·4	80	50	49·5
BHC 2% Sulphur dusts in ratio 1 : 1	60	80	0	0	31·0	1·0	70	0	16·0
BHC 2% dust	60	0	80	0	64·4	52·3	30	40	58·3
Sulphinette 1 oz. in 1 gal. water ..	0	60	0	0	48·4	44·6	30	0	46·5
Toxaphene 46% EC 20cc. in 1 gal. water	0	0	20	0	50	30	0	10	40·0
Toxaphene 40% W.W.P. 22gm. in 1 gal.	0	40	0	0	40·3	34·0	20	0	37·1
Untreated check ..	100	80	60	0	31·0	63·8	90	30	47·4

virus, "little leaf" and yellowing symptoms on the leaves. Mite incidence was low on the trial plots so that the acaricidal value of the sprays could not be tested. All treatments gave some control of thrips and thrips-caused leafcurl. The spray treatments did not influence the low incidence of vein-clearing virus disease nor the leaf mottle virus disease nor the so called "little leaf" disease. The symptoms of leaf yellowing while being present in all plots was present in more plants in the metasystox, diazinon and toxaphene treated plots and markedly so in the check plots. The incidence of this symptom within the various treatments themselves was erratic and further work is necessary for conclusions on the influence of spray on the incidence of leaf-yellowing symptoms.

Subsequent trials were carried out on similar lines using higher dosages of systemic and contact insecticides with no positive results on chilli virus control.

DISCUSSION

The pests and diseases damaging the chilli crop in Ceylon are not peculiar to Ceylon but found in most parts of the world wherever chilli is cultivated. In Ceylon a species of a thrip and a mite have been shown to induce a form of leaf curl through the mechanical damage caused during feeding while two plant sucking bugs have been proved to transmit two virus diseases. Two further maladies of chilli designated "little leaf" and a mosaic disease have come to light recently but their casual basis has to be elucidated by further research.

In the investigations reported here experimental data have been put forward to show that eelworm and root disease are not involved as casual agents of the chilli leaf curl complex. The experiments on the transmission of the vein-clearing virus disease by *Bemisis inconspicua* and the leaf mottle virus bug *Aphis gossypii* are conclusive and the main elements of the virus-vector relationships have been established.

A notable gap in the knowledge of insect vector-virus relationship is the absence of any concrete data on the host range of the virus diseases of chilli and a detailed knowledge of the behaviour of the two vectors in their natural environment. Further research is called for on this aspect of the problem.

A wide spectrum of modern insecticides of a similarly wide range of mode of action has been tested both in Ceylon and in other parts of the world (Simmons 1957) for the control of chilli virus diseases

TABLE 2—Effects of Insecticidal Sprayings on the Control of Chilli Leaf Curl

Insecticidal Treatment	Frequency of Treatment	Leaf-curl incidence expressed as Percentage of Total Number of Plants in each Treatment							
		Plants with Leaf Curl			Plants Recovered after Treatment			Average of 3 Reps.	
		Rep. 1	Rep. 2	Rep. 3	Rep. 1	Rep. 2	Rep. 3	Plants with Curl	Plants Recovered
DDT 18% E.C. 1 fl. oz. in 1 gal. water ..	Monthly ..	0·33	0·35	1·37	95·45	95·24	84·62	0·68	88·43
	Fortnightly ..	0·33	0·67	0·35	96·97	84·62	94·44	0·45	92·01
DDT 18% E.C. 1fl. oz. in 3 gal. water ..	Monthly ..	6·12	0	1·37	76·32	100·00	66·67	3·74	80·99
	Fortnightly ..	2·05	0	2·39	81·82	100·00	74·07	1·48	85·29
Sulphur 50% W.W.P. 1 oz. in 1 gal. water	Monthly ..	7·22	2·59	2·84	31·34	81·58	75·76	4·21	62·89
	Fortnightly ..	2·17	2·38	4·36	79·31	65·0	62·86	2·97	69·05
Sulphur 50% W.W.P. 1 oz. in 3 gal. water	Monthly ..	4·75	3·11	17·77	80·82	57·14	29·17	8·54	59·04
	Fortnightly ..	3·11	1·69	17·75	79·07	79·17	27·77	7·51	62·0
Toxaphene 47% E.C. 1 fl. in 1 gal. water	Monthly ..	3·86	0·74	1·02	79·25	88·88	84·21	1·87	84·11
	Fortnightly ..	1·05	0	3·08	90·63	100·0	59·09	1·37	83·24
Toxaphene 47% E.C. 1 fl. oz. in 3 gal. water	Monthly ..	2·04	0·34	1·37	76·00	96·30	76·47	1·25	82·92
	Fortnightly ..	0·34	0·34	2·38	95·65	93·33	53·33	1·02	80·77
Untreated Checks ..		26·53	7·82	22·49	10·34	23·69	0	18·94	12·31
		26·37	13·36	29·83	14·44	4·88	0	22·85	6·44
		1·02	11·03	16·38	3·13	5·88	4·00	16·14	4·33
		14·81	15·70	25·59	6·38	2·13	1·30	18·7	3·27

TABLE 3—Effects of Insecticidal Treatment in the Incidence of Chilli Pests and Diseases

Insecticide and Formulation	Dilution of Insecticidal Formulation	Frequency of Treatment	Pest Infestation and Disease Incidence expressed as Percentage of Total Plants in Plots of 2 Replications					
			Mites	Thrips	Vein-clearing Virus	Yellowing of Leaves	Leaf Mottle Virus	Little leaf Disease
DDT 25% E.C	1 fl. oz. in 2 gal. water	F*	—	3·57	—	3·57	—	46·93
		M**	3·57	5·35	3·57	3·57	—	47·71
		C***	—	10·71	3·57	7·14	3·57	58·93
	1 fl. oz. in 1 gal. water.	F	—	—	—	8·93	1·78	46·43
		M	—	8·92	—	1·78	—	58·93
		C	—	—	—	1·78	—	42·85
DDT 50% WWP ..	1 oz. of each in 4 gal. water ..	F	—	—	—	5·35	3·57	—
		M	—	3·57	—	7·14	—	55·35
		C	—	—	—	5·35	—	33·93
Sulphur 50% WWP ..	1 oz. of each in 2 gal. water	F	—	3·57	—	5·35	—	5·35
		M	—	3·57	—	1·78	7·14	39·28
		C	—	7·14	—	7·14	—	30·35
Parathion 46·7% EC	1·5 cc in gal. water	F	—	3·57	—	3·57	—	57·14
		M	—	5·35	—	10·70	—	25·00
		C	1·78	7·14	—	5·35	10·71	41·07
	3 cc in 1 gal. water	F	—	3·57	—	7·14	—	55·35
		M	—	5·35	—	14·28	—	33·93
		C	—	5·35	—	3·57	1·78	14·25
Diazinon 60% EC ..	2 cc in 1 gal. water	F	—	5·35	1·78	16·07	5·35	33·92
		M	—	5·35	—	3·57	1·78	35·71
		C	—	1·78	—	8·93	—	16·07
	4 cc in 1 gal. water	F	3·57	8·92	1·78	12·50	—	17·86
		M	—	—	—	8·92	—	16·78
		C	—	5·35	1·78	7·14	1·78	30·36
Malathion 50% EC ..	4 cc in 1 gal. water	F	—	—	1·78	3·57	—	50·00
		M	—	1·78	—	12·50	1·78	33·92
		C	—	3·57	1·78	7·14	10·71	48·21
	8 cc in 1 gal. water	F	—	3·57	—	7·42	—	28·57
		M	—	—	3·57	1·78	—	53·57
		C	—	5·35	1·78	3·57	1·78	48·21
Toxaphene 47% EC ..	1 fl. oz. in 4 gal. water	F	—	—	1·78	32·14	1·78	14·28
		M	—	3·57	—	10·71	7·14	17·85
		C	—	1·78	—	23·21	1·78	23·21
	1 fl. in 2 gal. water	F	1·78	5·35	3·57	8·93	7·14	3·57
		M	—	3·57	7·14	7·14	3·57	25·00
		C	—	3·57	—	5·35	1·78	10·71
Metasystex 50% EC ..	2 cc in 1 gal. water	F	1·78	3·57	1·78	12·5	3·57	33·93
		M	—	5·35	1·78	10·71	—	51·78
		C	—	—	—	3·57	—	50·00
	4 cc in 1 gal. water	F	3·57	1·78	3·57	10·71	1·78	28·57
		M	3·57	3·57	—	5·35	—	48·21
		C	—	—	—	5·35	—	41·07
Ekatin 20% EC ..	2 cc in 1 gal. water	F	1·78	—	3·57	1·78	—	23·21
		M	—	10·07	—	21·4	3·57	48·21
		C	—	—	—	5·35	3·57	37·50
	4 cc in 1 gal. water	F	—	—	3·51	5·35	—	35·71
		M	3·57	3·57	—	10·71	3·57	62·50
		C	—	—	1·78	7·14	1·78	38·93
Untreated Check Plots		—	—	17·35	1·78	21·42	1·78	51·78
		—	—	19·64	—	25·0	7·14	26·78
		—	1·78	12·50	5·35	14·28	3·57	32·14
		—	3·57	16·07	3·57	8·93	—	35·71
		—	—	12·50	—	10·71	1·78	49·64
		—	—	3·57	1·78	7·14	—	16·07

*Fortnightly, **Monthly. ***Onset of curl.

with no satisfactory results. Thrips and mite-induced leaf curl are controllable with insecticides as has been demonstrated. The failure of insecticides to control the virus diseases of chilli to date should however not preclude the possibility of using this weapon for timely control chemically of the vectors in their breeding sites or at plant barriers which remains to be explored.

The notable success of insecticides and fungicides in crop protection during the last decade has resulted, in Ceylon as in all other parts of the world, in a tendency among cultivators to expect the control of all plant pests and diseases by chemical methods without regard for implementation of certain essential cultural practices which could prove as valuable or, under certain conditions, more valuable than purely chemical techniques of control. Factors such as the continuous cultivation of solanaceous crops without a break, the neglect to destroy crop residues and the absence of the practice of clean weeding before and during chilli cultivations in Jaffna have resulted in the build-up and perpetuation of an enormous pest population and reservoir of virus diseases which are bound to take a heavy toll of any crop. The importance of implementing these cultural practices for the reduction of leaf curl incidence has yet to be recognized by chilli cultivators.

On the basis of our studies conducted to date the following recommendations are made for the control of chilli leaf curl—

(i) Cultivation of solanaceous crops in strict rotation.

(ii) Destruction of crop residues immediately after the last main harvest.

(iii) Clean cultivation before and during cropping.

(iv) Application of insecticides to achieve control of the chilli thrips and mites.

The most fruitful line of action in the solution of the leaf curl problem of chilli is the selection and breeding of disease-resistant plants of chilli varieties. This work has already been taken in hand by the Department of Agriculture. The incidence of chilli diseases in certain other parts of Ceylon as noted from preliminary observations is frequently not as heavy as in the Jaffna peninsula. A detailed survey of the incidence of chilli maladies in various parts of the country may provide valuable information on better locations for chilli cultivation from a pest and disease standpoint.

SUMMARY

1. In addition to the six chilli maladies reported earlier on chilli two more have been recognized as the "little leaf" disease and a mosaic, the causal basis of which in either case is not yet understood.

2. Virus-vector relationships have been established for vein-clearing virus disease and the leaf mottle virus disease and the vectors recognized as *Aphis gossypii* and *Bemisia inconspicua* respectively.

3. The vein-clearing virus has been transmitted to tomato and tobacco, and on the basis of its symptom expression in the latter plant has been classified as the transparent kroepoek strain of the tobacco leaf curl virus.

4. The factors responsible for the high incidence of chilli pests and diseases in the Jaffna peninsula are the cultivation of *Solanaceae* with little effort at rotation, the non-destruction of crop residues soon after harvest and the neglect to clean weed before and during chilli cultivations.

5. Tests with a wide range of modern organic systemic and contact insecticides even at very high dosages have only controlled thrips and mite-induced leaf-curls but not virus-caused leaf curls of chilli. These findings are in line with those obtained in India and U. S. A.

6. Breeding for virus-resistant varieties of chilli appears at present to be the most fruitful line of attack on this problem.

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CORRELATIONS BETWEEN SEED-NUT, SEEDLING AND ADULT PALM CHARACTERS IN COCONUT

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INTRODUCTION

In a perennial crop like coconuts, *Cocos nucifera* L., where the only known method of propagation is by seed, any morphological characters either of the seed-nut, or the seedling, that demonstrate the yield potentialities of the young or the adult palm, are of considerable economic value. The importance of such an assessment cannot be over-emphasised, since the available planting material is so heterozygous and as such, even after years of careful crop husbandry a number of palms tend to be unproductive in a plantation.

Correlation studies made so far regarding coconuts by different workers, have been limited to the characters of the adult palm, *e.g.* the correlation between number of leaves on a crown and the yield of the palm, etc. These studies, are useful no doubt, in the selection of suitable seed parents, but do not indicate the behaviour of their offspring.

The present study was undertaken to determine, whether any of the young progeny characters predispose towards certain desirable characters, particularly high-yield of nuts or copra of the adult progeny.

MATERIAL AND METHODS

A field trial was laid down in 1939 to study methods of mass selection of the coconut palm (*Cocos nucifera* L. var. *typica*). Altogether 576 seedlings have been transplanted, and out of them, there are 144 plants whose seed parents are known with at least 4 progenies per family, *i.e.* per seed parent. These 144 progenies, that have been planted amidst the other plants, have been used for the present study.

The seed material has been collected from 20 selected high-yielding palms under open pollination, planted in a nursery and subsequently seedlings have been transplanted in the field.

The following data have been collected during different stages of the experiment.

Seed-nut: Weight and volume of unhusked nut and date of sprouting. The sprouting period is the period taken

from the date of planting of a seed-nut to the date of emergence of the sprout (shoot) from the husk.

Seedling: Height, leaf number and root number eight months after planting seed-nuts. Vegetative weight is the total weight of the seedling less the weight of the unhusked nut.

Adult palm: Date of initial flowering, total yield of nuts and weight of husked nuts *gathered during the 16th and 17th years after planting.* Yield of copra has been calculated as 32 per cent of the husked-nut weight.

A summary of the data collected is presented in Appendix 1.

The correlation coefficients between and within families of the characters listed above, and in some instances the partial coefficients keeping one or two factors constant have been worked out. The significance levels of the correlation coefficients are given below.

			Between r	Within r
P = 0·01 (denoted with *** in the text)		r =	0·5466	0·2324
	Partial	r =	0·5591	0·2324
P = 0·05 (denoted with ** in the text)		r =	0·4316	0·1778
	Partial	r =	0·4434	0·1778
P = 0·1 (denoted with * in the text)		r =	0·3680	0·1497
	Partial	r =	0·3774	0·1497

RESULTS

Seed-nut Volume

TABLE 1—Correlations between the Volume of a Seed-nut and the Other Characters

		Between r	Within r
Seed-nut volume	× Seed-nut weight ..	+ 0·8703***	+ 0·6625***
,,	× Seed-nut weight per unit volume	— 0·3788	— 0·7015***
,,	× Sprouting period ..	— 0·0247	— 0·0134
,,	× Seedling height.. ..	+ 0·1762	+ 0·1083
,,	× Seedling weight ..	+ 0·8547***	+ 0·4893***
,,	× Seedling vegetative weight ..	+ 0·3640	+ 0·3069**
,,	× Seedling leaf number ..	— 0·0146	+ 0·2163**
,,	× Seedling root number ..	— 0·0266	+ 0·1086
,,	× Flowering period of palm ..	+ 0·3019	+ 0·2206**
,,	× Weight per nut of palm ..	+ 0·2904	— 0·0571
,,	× Yield of nuts of palm ..	— 0·5598***	— 0·1117
,,	× Yield of copra of palm ..	— 0·3597	— 0·0974
Partial coefficients keeping flowering constant.			
Seed-nut volume	× Weight per nut of palm ..	+ 0·5631***	+ 0·0421
,,	× Yield of nuts of palm ..	— 0·4955**	+ 0·0376

The volume of a seed-nut has no bearing at all on its sprouting period, height and root number of seedling or yield of copra of the adult palm.

Within a family *i.e.* for seed-nuts taken from the same mother palm, the larger seed-nuts produce seedlings with a heavier weight and more leaves and these seedlings flower relatively late. The high positive correlation between seed-nut volume and seedling weight is presumably due to the common seed-nut weight; yet when the vegetative weight is correlated with volume, the high significance is retained, indicating that the larger seed-nut promotes better vegetative growth.

There is a high negative correlation for between families only, between volume of seed-nut and yield of nuts of progeny, suggesting that seed parents that give nuts of above average size have progenies with fewer nuts. Even if flowering is kept constant the same relationship holds, indicating that the relationship is valid irrespective of the bearing age.

Seed-nut Weight

TABLE 2—Correlations between the Weight of a Seed-nut and the Other Characters

		Between r	Within r
Seed-nut weight	× Weight per unit volume of seed-nut	+ 0·1158	+ 0·0166
,,	× Sprouting period ..	+ 0·0955	— 0·0715
,,	× Seedling weight ..	+ 0·8672***	+ 0·5012***
,,	× Seedling height.. ..	+ 0·0193	+ 0·1875**
,,	× Seedling vegetative weight ..	+ 0·1913	+ 0·0840
,,	× Seedling leaf number ..	+ 0·0460	+ 0·2093**
,,	× Seedling root number ..	+ 0·0191	+ 0·1182
,,	× Flowering period ..	+ 0·2865	+ 0·0804
,,	× Weight per nut of palm ..	+ 0·3032	+ 0·0220
,,	× Yield of nuts of palm ..	— 0·5351**	— 0·0581
,,	× Yield of copra of palm ..	— 0·0422	— 0·0374
Partial coefficients keeping flowering period constant.			
Seed-nut Weight	× Weight per nut of palm ..	+ 0·5660***	—
,,	× Yield of nuts of palm ..	+ 0·4724**	—

The weight of a seed-nut has no bearing on the sprouting period or vegetative weight and root number of a seedling, or the flowering period of the progeny. A heavy seed-nut gives rise to a heavy seedling, but since there is no significant correlation between seed-nut

weight and vegetative weight, it is apparent that the former correlation is purely due to the common seed-nut weight. A heavy seed-nut shows a tendency to produce more leaves in the seedling, but since the between parent correlation is not significant, it does not follow that a seed palm normally bearing heavy nuts would necessarily give rise to progenies with more leaves.

The weight of a seed-nut has no significant bearing on the nut weight of its progeny. The partial coefficient between these two factors, keeping the flowering period constant, is significant only for between parents. Therefore, although there may be nothing to be gained by selecting heavy seed-nuts within parents, it does help to an appreciable extent, if seed palms that normally give heavy seed-nuts are selected.

The weight of a seed-nut has no bearing on nut production of its progeny, if the selection is done within the parent ; but the between parent correlation is negative and significant, *i.e.*, parents which normally bear heavy nuts would give progenies with fewer nuts.

Seed-nut Weight per Unit Volume

TABLE 3—Correlations between Weight per unit Volume of Seed-nut and the Other Characters

		Between r	Within r
Weight per unit volume of seed-nut	× Sprouting period ..	+ 0·2870	— 0·0989
,,	× Seedling height ..	— 0·3562	+ 0·0457
,,	× Seedling weight ..	— 0·1159	— 0·2894***
,,	× Seedling vegetative weight	— 0·4040	— 0·3418***
,,	× Seedling leaf number ..	+ 0·0717	— 0·0857
,,	× Seedling root number ..	— 0·1267	— 0·0561
,,	× Flowering period ..	— 0·0166	— 0·2260***
,,	× Weight per nut of palm ..	— 0·0736	+ 0·0916
,,	× Yield of nuts of palm ..	+ 0·1276	+ 0·1303
,,	× Yield of copra of palm ..	+ 0·0961	+ 0·0999

The weight per unit volume of seed-nut has no significant bearing on the sprouting period ; or height and root number of seedling ; or weight per nut, yield of nuts and weight of copra of the adult palm. Within families, *i.e. if* we limit consideration to seed-nuts from the same mother palm, nuts of high weight per unit volume tend to inhibit vegetative growth and promote early flowering.

Sprouting Period

TABLE 4—Correlations between the Sprouting Period of a Seed-nut and the Other Characters

		Between r	Within r
Sprouting period	× Seedling height	— 0·9348***	— 0·8110***
,,	× Seedling weight ..	— 0·0378	— 0·0891
,,	× Seedling vegetative weight ..	— 0·2192	— 0·0671
,,	× Seedling leaf number ..	— 0·2768	— 0·3529***
,,	× Seedling root number ..	— 0·2756	— 0·3758***
,,	× Flowering period of palm ..	+ 0·5468***	— 0·0271
,,	× Weight per nut of palm ..	— 0·3429	— 0·0145
,,	× Yield of nuts of palm ..	+ 0·0026	— 0·1545*
,,	× Yield of copra of palm ..	— 0·1777	— 0·1411
Partial coefficients keeping flowering constant.			
Sprouting period	× Weight per nut of palm ..	— 0·0694	—
,,	× Yield of nuts of palm ..	+ 0·3762	— 0·2706***

Early sprouting promotes seedling height, leaf and root number. This may be largely due to the higher physiological age. (age being reckoned from the date of sprouting) of the seedlings that sprout early rather than to other causes.

Within a family one cannot expect seed-nuts that sprout early to produce palms that flower early and vice versa, but between families the correlation is highly significant and positive, showing that a family with a low sprouting period will have a low flowering period.

The sprouting period has no significant bearing on nut production, but when flowering is kept constant, the within correlation is highly significant and negative. The position, then, is that early sprouting, in spite of the bearing age will bring about a higher nut production.

Seedling Height

TABLE 5—Correlations between the Height of a Seedling and the Other Characters

		Between r	Within r
Seedling height	× Seedling weight ..	+ 0·2472	+ 0·2599***
,,	× Seedlirg vegetative weight ..	+ 0·4575**	+ 0·2115**
,,	× Seedling leaf number ..	+ 0·3336	+ 0·3463***
,,	× Seedling root number ..	+ 0·2974	+ 0·4155***
,,	× Flowering period of palm ..	— 0·5478***	+ 0·0353
,,	× Weight per nut of palm ..	+ 0·4586**	— 0·0264
,,	× Yield of nuts of palm ..	+ 0·0039	+ 0·0821
,,	× Yield of copra of palm ..	+ 0·0205	+ 0·0075

The seedling height has a significant bearing on seedling weight and the same relationship holds when the sprouting period is kept constant *i.e.* when the seedling age is the same.

If seedlings from the same parent are considered, it is found that taller seedlings have more leaves. But when sprouting period is kept constant, this correlation disappears, indicating that this relationship is merely a reflection of seedling age.

Within the same seed parent, a taller seedling signifies more roots. But the non-significant between parent correlation suggests that seed parents which normally give tall seedlings would not necessarily find them with more roots. This situation does not change appreciably even after sprouting is kept constant.

If the seedlings are from the same seed parent, the seedling height has no bearing on the flowering period, but the significant negative correlation between parents suggests that seed parents that normally give tall seedlings will find their offspring flowering early. However, if the sprouting period is kept constant, this association disappears (partial for *between* r = — 0.1235, *within* r = — 0.0227) and in effect the seedling height by itself can be considered to have no bearing on the flowering period of palms.

Within the same seed parent the seedling height has no effect on the weight per nut or the yield of nuts or copra of the adult palm. The significant correlation between height of seedling and weight per nut for between parents too disappears when sprouting and flowering are kept constant.

Seedling Weight

TABLE 6— Correlations between Seedling Weight and the Other Characters

		Between *r*	Within *r*
Seedling weight	× Seedling leaf number ..	+ 0·2535	+ 0·1108
..	< Seedling root number ..	+ 0·2120	+ 0·1400
..	· Flowering period of palm ..	+ 0·1588	+ 0·0477
..	× Weight per nut of palm ..	+ 0·3872*	— 0·0963
..	< Yield of nuts of palm ..	— 0·3838*	— 0·0165
..	< Yield of copra of palm ..	— 0·1780	— 0·0231

The weight of a seedling bears no influence on its leaf or root number or the flowering period of the palm. The same pattern holds even when the sprouting period is kept constant.

Within a family, the seedling weight has no effect either on the weight per nut or the yield of nuts. But between parents, the correlation between seedling weight and weight per nut is suggestive, and it is so (—0.3986) even when the sprouting period is kept constant. But the correlation is highly significant (—0.5534) when both sprouting and flowering periods are kept constant.

Thus, if we eliminate the effect of sprouting and flowering periods, a heavy seedling tends to give heavy nuts in the bearing palm. The suggestive between correlation with regard to seedling weight and yield of nuts disappears when both the flowering period and sprouting period are kept constant. This indicates that weight of a seedling by itself has no influence on the number of nuts produced by the adult palm.

Seedling Leaf Number

TABLE 7—Correlation between Seedling Leaf Number and the Other Characters

		Between r	Within r
Seedling leaf number	× Root number ..	+ 0·6637***	+ 0·5761***
,,	× Flowering period ..	— 0·0150	+ 0·0914
..	× Weight per nut of palm ..	+ 0·1613	+ 0·0075
..	× Yield of nuts of palm ..	— 0·0534	+ 0·0704
..	× Yield of copra of palm ..	+ 0·0196	+ 0·0834

There is a highly significant positive correlation between the leaf number and root number of a seedling and the same pattern holds even when the sprouting period is kept constant. Besides this factor, there are no relationships between leaf number of a seedling and the flowering period or the yield of the adult palm.

Seedling Root Number

TABLE 8—Correlations between the Seedling Root Number and the Other Characters

		Between r	Within r
Seedling root number	× Flowering period of palm ..	— 0·0953	+ 0·0618
..	× Weight per nut of palm ..	+ 0·0864	+ 0·0293
..	× Yield of nuts of palm ..	+ 0·0120	+ 0·0347
,,	× Yield of copra of palm ..	+ 0·0316	+ 0·0013

The number of roots of a seedling has no bearing at all with any of the palm characters, *i.e.* flowering period, weight per nut, or the yield of nuts and copra.

Flowering Period

TABLE 9—Correlations between the Flowering Period and Other Characters

	Between r	Within r
Flowering period × Weight per nut of palm ..	— 0·5375**	— 0·4268***
,, × Yield of nuts of palm ..	— 0·4957**	— 0·6348***
,, × Yield of copra of palm ..	— 0·6236***	— 0·5525***
Partial coefficients (Sprouting period constant).		
Flowering period × Weight per nut ..	— 0·4450**	— 0·4276***
,, × Yield of nuts of palm ..	— 0·5938***	— 0·6470***

The period taken for flowering of a palm is negatively correlated (both between and within parents) with weight per nut and yield of nuts and copra of the adult palm *i.e.* a palm that flowers early will give a higher yield both of copra and nuts than those that flower late. These relationships hold irrespective of the sprouting period.

Initial Yield

TABLE 10—Correlations between initial yield and yield in the 16th and 17th Years

	Between r	Within r
Initial yield of nuts × Yield of nuts in the 16th and 17th years	+ 0·8861***	+ 0·7369***
,, × Yield of copra in the 16th and 17th years	+ 0·9216***	+ 0·7389***
Partial correlation coefficients (keeping flowering period constant).		
Initial yield of nuts × Yield of nuts in the 16th and 17th years	+ 0·8699***	+ 0·6856***
,, × Yield of copra in the 16th and 17th years	+ 0·9299***	+ 0·7119***

The initial yield is the mean of the harvests gathered during the second and third years of bearing. The first year of bearing has not been considered, as invariably during that year only a few harvests have been collected. All the correlation coefficients listed in Table 10 are highly significant. If a palm during the second and third years of bearing gives a high yield, then these palms would continue to be high-yielding subsequently.

DISCUSSION

General. The sprouting period of a seed-nut and the flowering period of a palm are two important physiological stages in the development of the life cycle of a coconut palm. The former seems to influence the growth

of a seedling and the latter the yield (figs. 1 & 2). The size or the weight of a seed-nut apparently has no effect on the period taken for its sprouting, but early sprouting promotes height, weight and leaf-number of the seedling, probably due to its higher physiological age.

Considerable care has to be taken in the definition of the term " early sprouting ". The germination of a seed-nut depends on its genetic constitution and the environment—particularly soil moisture. Seed-nuts planted at different seasons may have varying sprouting periods, purely due to different climatic conditions as illustrated in Table 11, which has been prepared from data collected by the senior author in implementing a programme of in-breeding work. The age of seed-nuts has been calculated from the date of opening of the inflorescence to the date of planting of ripe nuts from that inflorescence. It is seen that the age of seed-nuts from the different palms is practically the same. Yet there are two marked differences apparent : the variations in the means between families and the variations in the sprouting period of nuts within families.

TABLE 11—The Sprouting Period of Intred Seed Coconuts

Cross	Age of seed-nuts (months)	Frequency of nuts sprouting in the following periods (days)						Non germinations	Mean sprouting period (days)	Range (days)
		75–89	90–104	105–119	120–134	135–149	>150			
Seed-nuts planted in September, 1956										
34 selfed ..	14·1	1	7					1	97	15
37 selfed ..	14·6		8	3				0	101	27
35 selfed ..	14·3	1	3	1		2	1	0	113	61
198 selfed ..	14·9	3	2	2				0	96	37
21 selfed ..	15·1	1	4	2	1			1	101	42
402 selfed ..	14·3	2	5			1		0	101	54
15 selfed ..	14·2		3	3				0	104	23
66 selfed ..	14·4		1	5				0	105	14
290 selfed ..	14·1		3	4	3			0	113	29
196 selfed ..	14·5		1	1	3	1		0	125	49
Seed-nuts planted in April, 1957										
72 selfed ..			9	1				0	81	24
315 selfed ..			6	1				0	86	10

Seed-nuts of some families have sprouted more or less together, whereas in others, the period between the first and the last to sprout has been considerable. In the families 34, 66, and 315 the range in the sprouting period is less than 16 days, but in the families 35 and 196 the range is 61 and 49 days respectively. Since this is inbred material, it is clear that the degree of heterozygosity relative to the sprouting period of seed-nuts varies between families.

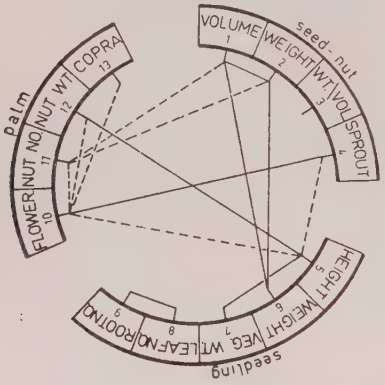

Fig. 1.—The significant correlations *between* parents.

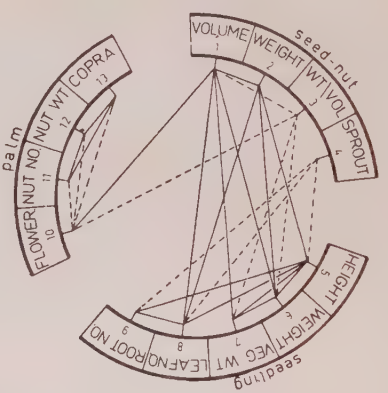

Fig. 2.—The significant correlations *within* parents.

(*All correlations are significant at least at 5 per cent. level. A continuous line joining two characters indicates a positive correlation and a discontinuous line a negative correlation.*)

The mean sprouting period of the two families 72 and 315 planted in one season is extremely low, whereas that of 196 and 290 planted in another season is very high (Table 11). These differences may be due purely to seasonal effects, and it does not follow that nuts of palms 72 and 315 sprout earlier than those of 196 and 290. Hence the term "low sprouting period" cannot be defined precisely, but in selection work, seed-nuts that sprout early from a pool of nuts planted at the same time could be picked out from the nursery beds.

The sprouting period and the flowering period are significantly correlated ($r = + 0.5468$) for between parents only, and is significant at $P = 0.01$, *i.e.*, palms that give seed-nuts with a low sprouting period will have progenies with a relatively low flowering period. Although, the sprouting period is not directly correlated with yield, the within correlation is significant and negative when flowering is kept constant (Table 4). Thus, it is an advantage to select seed-nuts for early sprouting, in that it brings about a higher nut production, besides early flowering.

The flowering-period of a palm is negatively and significantly correlated with weight per nut, yield of nuts and yield of copra of the adult palm (Figs. 1 and 2). That is, a palm that flowers early would be more productive than one that flowers late. This correlation is of considerable significance, since the bearing age of a palm which is normally one year more than the flowering period, is an important economic consideration. Further, the yield of the second and third years of bearing has a relation to the yielding capacity of the adult palm (Table 10). All the palms, except one, that have flowered in less than 102.5 months and have given an initial yield of 40 nuts or more per year, have given more than 70 nuts per year during the 16th and 17th years (Fig. 3).

Thus, the flowering period and the initial yield of a palm are two criteria of considerable value in thinning out unproductive palms in a plantation, a practice which would materially benefit the industry. The mean initial yield per year is 30.7 nuts with a standard deviation of 18.7, so that palms giving an initial yield of 12 nuts or less per year (*i.e.*, mean less the standard deviation) would be a suitable standard for thinning-out stands. On a basis of mathematical probability about 16 per cent of the stand would be in this yield group.

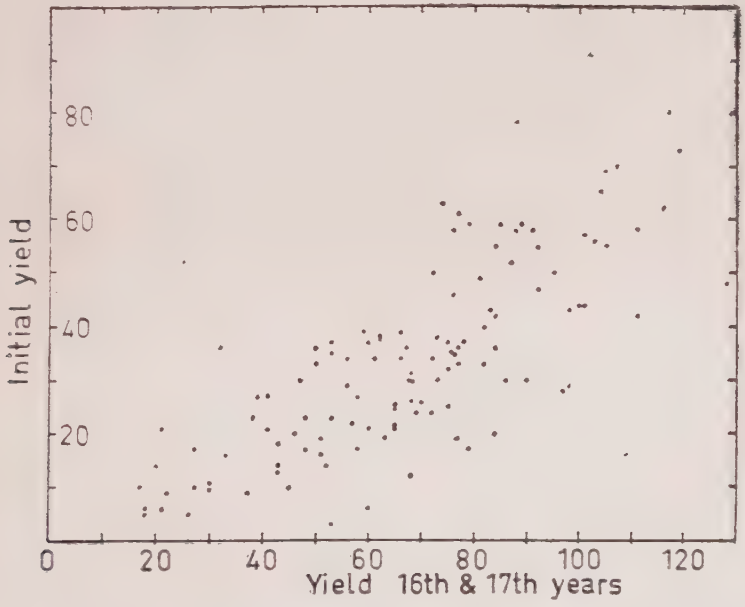

Fig. 3.—Mean yield of nuts per year in the 2nd and 3rd years of bearing (initial yield) and the 16th and 17th years after planting.

Unfortunately, the current system of planting coconut palms in a very symmetrical way at the corners of a geometrical figure, is not very conducive to roguing. The main draw-back being that, when (say) a 8 year old palm is poor and has to be uprooted, a fresh seedling has to be supplied and thereby 8 years of growth is lost. To overcome this factor, the senior author has suggested a system of *Hedge Planting* whereby about 25 per cent more seedlings are transplanted than are necessary, so that even after thinning out the unproductive palms, the required density is maintained. In the present material, if the palms flowering later than 9 years and those with an initial yield of 12 nuts or less per year have been thinned out, approximately 25 per cent. of the stand would have been rejected.

Optimum Yield of Palms. The four adult palm characters considered in the present study are the flowering period, weight per nut and yield of nuts and copra. The last three factors represent the harvests gathered from the palms during the 16th and 17th years after planting—*i.e.* the current age of the plantation. How far are we justified in taking the yield of these two years as the optimum or the mature yield of a coconut palm ?

The variety of coconut palms grown in Ceylon on a plantation scale flowers initially in 6 to 8 years and remains productive for over 50 years depending on soil, climate and crop husbandry. After initial flowering, the yield of nuts increases progressively every year, until an optimum yield is attained, which is continued thereafter depending on the environment. Unfortunately, there is no data available to ascertain when the optimum yield of a palm is attained. Figure 4 exemplifies this point to a certain extent.

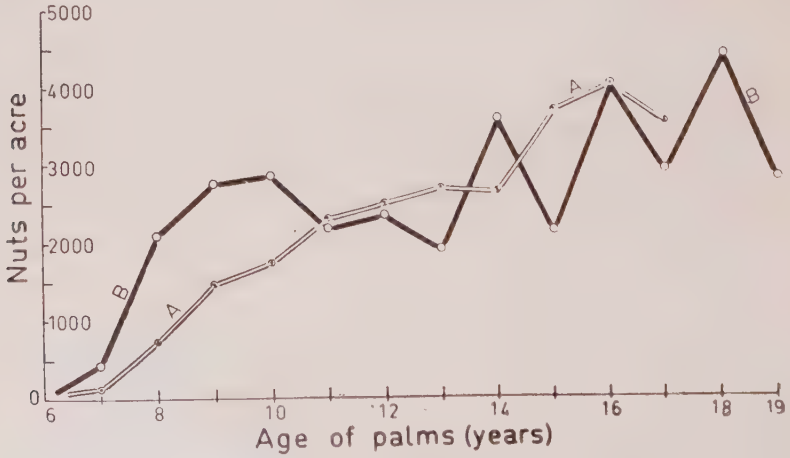

Fig. 4.—The yield curves of two populations of coconut palms.

Curve A gives the yearly yield of nuts per acre of a 12 acre block (say block A) from the 6th to the 17th year after planting. The present correlations have been worked out from this population. Curve B presents the yearly yield of nuts per acre of a 5 acre block (say block B) from the 6th to the 19th year after planting. Yield of both blocks for the subsequent years are not available.

Block A is of lateritic gravel and block B is clayey. The total rainfall over both blocks is practically the same, but distribution varies—B has a more erratic distribution than A. The yearly fluctuations of yield of block B are due to a poor rainfall regime combined with a less favourable soil for coconuts.

The yield of block A has been increasing progressively from the 6th to 16th year and in the 17th year there has been a drop, largely due to a severe drought in the previous year. Considering the soil and climatic conditions, 4,000 nuts per acre per year of block A is reasonably good. It is not possible to say definitely whether the palms in this block have reached their optimum yield until further data are collected ; yet it could be safely stated that it is in reasonably full bearing.

The pattern of curve B is different. The yield has progressively increased up to the 10th year and thereafter the fluctuations have been considerable ; every alternate year the yield has been low. Maximum yield (4500 nuts per acre) has been obtained in the 19th year. It may be that, if climatic conditions had been more favourable, 4,500 nuts per acre would have been obtained much earlier.

From the above evidence it is not possible to conclude that the optimum yield of a coconut palm is derived in the 16th and 17th years ; but it is clear that during this age of the palm a reasonably good yield is obtained. Further, the yields of the 16th and 17th years are representative of the total harvest gathered from the 6th to 17th years *i.e.* the first 12 years of bearing of the plantation, as the following correlation coefficients are significant at $P = > 0.01$.

	Between r	Within r
Yield of nuts of the 16th and 17th years × total yields of nuts from the 6th to 17th year ..	+ 0·9507***	+ 0·9277***

Re-assessment of Selection Criteria. It is necessary to ascertain the relevance of the present study on the current standards of selection of planting material in coconuts. The current practice is to collect seednuts from high-yielding mother palms or high-yielding blocks. Mother

palms are selected on the following criteria : trunk straight and stout with leaf-scars placed close to each other ; fronds short and well-dispersed on the crown ; bunch stalks short ; nuts medium-sized, extra large nuts to be avoided ; weight of husked-nuts to be high ; bearing should not be seasonal ; total yield to be over 100 nuts with at least 50 lb. of copra per palm per year. In the other category of seed selection, *i.e.*, block nuts, a high-yielding block (giving about 4,000 nuts per acre per year) is selected ; all the palms within the block are harvested and heavy and medium-sized nuts are selected from heap, irrespective of the variations between palms in that population, Obviously, such a method of seed selection is genetically not very sound.

Seed-nuts are put down in a nursery and seedlings are selected on early sprouting and vigour before transplantation. Vigour is a rather relative measurement and is an expression of rate of growth and sturdiness of the seedling (Coconut Research Institute Leaflets Nos. 1, 2 and 14).

Some pertinent factors that are overlooked in the selection of seed palms are apparent from Figure 1. A palm having large or heavy seed-nuts tends to give offspring with fewer nuts, but since the total yield of copra is not affected, it is not a disadvantage. On the other hand it is an advantage if the nuts are large and heavy, since fewer nuts would be required for a ton of copra, thereby reducing the cost of production. The volume of seed-nuts used in the present study has varied between 1349 and 4165 c.c., with a general mean of 2684 c.c. (appendix I). A nut of volume 4000 c.c. (approx.) which is ideal for seed purposes, both in shape and size is illustrated in Figure 5.

Further, a seed parent that gives progenies with a low sprouting period (other seedling characters being good) will have the same progenies bearing early. Therefore, after the preliminary selection of seed parents as pointed out earlier, it is advantageous to select those that give nuts with a low sprouting period, provided they are vigorous. There is another advantage that accrues due to selection of families in this manner. It is the experience of the senior author, that some seed palms give a higher percentage of vigorous seedlings than others—in some instances 80 to 85 per cent—so that if a large number of such seed-bearers could be selected, the quantity of rejected seedlings would be negligible. At present 50 to 60 per cent seedlings are rejected as poor from bulked material.

The nut size and weight within a family have important considerations on seedling characters ; the larger seed-nuts give seedlings with more leaves ; the heavier nuts give taller seedlings with more leaves (Figure 2). Since vigour, which is an expression of leaf number, height

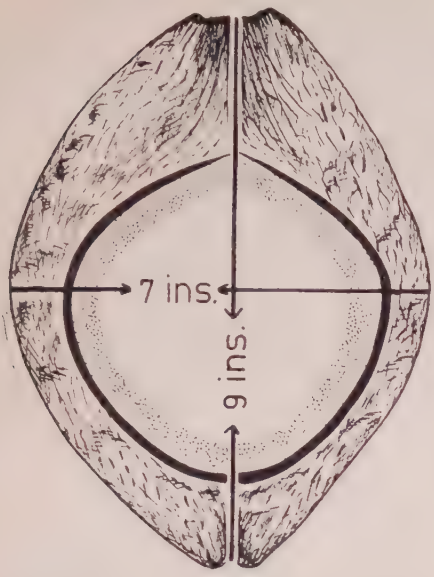

Fig. 5—An ideal form of seed-coconut, approximately 4000 c.c. in volume.

of seedling etc., as pointed out earlier, is an important criterion in seedling selection, nuts should be selected for their larger size and greater weight within families.

Thus, in the selection of seed-palms, besides the morphological characters listed in the Coconut Research Institute (Ceylon) leaflets, it is desirable to select palms giving heavy nuts with about 4000 c.c. volume that sprout early and produce a high percentage of tall and vigorous seedlings.

SUMMARY

Correlations between 14 characters pertaining to seed-nut, seedling and adult palm in Coconuts have been worked out in order to ascertain whether any of the young progeny characters predispose towards economic qualities of the adult progeny.

Besides the criteria already considered in the selection of seed parents, it is desirable to select palms that give large and heavy seed-nuts with a low sprouting period. Early sprouting of a seed-nut, early flowering and high initial yield of a young palm are reliable characters of a high-yielding adult palm.

(*Received 17 February 1958*)

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APPENDIX I

A summary of data pertaining to seed-nut, seedling and adult palm characters in Coconut

Family No.	No. of Progenies	Seed-nut						Seedling								Palm			
		Sprouting Period		Weight		Volume		Height		Weight		Leaf No.		Root No.		Flowering Period		Yield of Nuts 16 & 17 years	
		Mean (days)	Range (days)	Mean (gms.)	Range (gms.)	Mean (c. c.)	Range (c. c.)	Mean (in.)	Range (in.)	Mean	Range	Mean	Range	Mean	Range	Mean (mths.)	Range (mths.)	Mean per year	Range per year
1	10	135	115–162	1410	1350–1511	3644	3208–4165	53	32–67	2070	1600–2600	3	2–4	5	3–8	88	65–143	48	21–77
2	15	149	126–174	1159	1055–1287	2329	1791–3332	38	21–53	1516	1150–1800	2	2–3	5	1–8	92	68–148	71	16–116
3	7	154	140–169	1585	1457–1798	3158	2832–3749	34	25–42	2064	1700–2400	2	2–2	5	3–7	87	68–102	55	33–75
6	9	145	113–164	1614	1366–1853	3382	2832–3915	43	27–58	2088	1600–2400	2	1–2	5	3–7	81	65–98	55	17–98
7	6	144	128–173	1429	1297–1503	3001	2815–3248	34	16–42	1608	1500–1850	2	1–2	5	4–6	97	69–161	46	3–105
8	6	170	145–196	1533	1465–1620	3900	3682–4082	28	11–45	2266	2000–2600	1·5	1–2	5	3–6	104	77–155	60	2–104
9	12	141	113–169	1074	890–1260	2684	1983–3374	46	28–69	1562	1250–2050	2	2–3	6	4–8	80	68–89	58	27–82
10	5	131	104–160	1238	1132–1338	2840	2291–3290	48	31–64	1740	1500–2200	2	2–2	7	5–9	90	74–101	31	18–45
11	5	188	180–206	771	722–862	1597	1349–1774	11	5–17	1160	1000–1400	1	1–2	4	2–7	85	68–103	81	65–128
12	12	163	143–197	1088	968–1294	2307	1699–2899	28	10–44	1583	1200–1850	3	1–6	6	2–9	98	72–137	52	20–85
14	4	152	144–163	1955	1891–2130	3689	3082–4082	43	39–50	2837	2100–3200	4·5	4–5	9	9–10	88	80–103	49	34–58
16	6	127	108–143	932	748–1042	1984	1790–2191	56	44–71	1583	1360–1750	3	2–4	5	5–6	80	70–93	65	50–84
21	6	138	129–151	1348	1205–1505	2680	2540–2874	52	45–63	2066	2000–2200	2	1–3	5	4–7	76	70–80	76	48–115
24	5	132	97–155	1047	953–1109	2400	2166–2599	53	40–74	1550	1350–1800	2	2–3	6	4–10	68	54–83	75	18–111
25	7	134	124–154	989	898–1150	2182	1524–2790	46	39–54	1450	1200–1800	3	2–5	6	5–10	78	62–91	83	60–119
27	6	150	134–160	1117	1004–1380	2294	2082–2599	44	32–62	1875	1700–2200	2	1–3	4	4–6	82	66–104	73	15–98
28	7	140	129–159	957	835–1170	2027	1624–2732	41	32–50	1407	1250–1600	3	2–6	6	5–11	88	68–128	62	20–107
B 1	5	137	113–150	960	860–1007	2610	2124–2915	47	39–66	1750	1500–2000	2	2–5	8	6–11	80	68–89	90	73–116
B 2	5	125	107–139	1213	1038–1283	3209	2999 3515	59	50–76	2170	1900–2650	2	2–3	6	6–8	91	68–115	55	22–100
B 23	6	125	109–137	948	888–1033	1987	1749–2249	47	40–56	1491	1200–1800	2	2–3	5	4–8	72	67–78	75	41–101
General Mean		145	—	1212	—	2684	—	42·3	—	1757	—	2·3	—	5·8	—	86·4	—	62·7	—

INVESTIGATIONS ON THE CONTROL OF THE PADDY STEM FLY *ATHERIGONA* SP. (FAM. ANTHOMYIIDAE ORD. DIPTERA.)

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INTRODUCTION

Many species of the genus *Atherigona* of the Anthomyiid family of the Diptera are pests of economic importance in the larval stages. In Queensland *Atherigona* sp. is recorded as attacking the central hearts of sugarcane seedlings (Bell 1939). In Indonesia *Atherigona exigua* Stein is a serious pest of dryland rice and also attacks maize (Van Der Laan 1951) while in North Africa *A. soccata* and *A. quadripunctata* attack sorghum and maize (Bleton and Fieuzet 1943). In Ceylon *Atherigona* sp. is a pest of rice seedlings especially on highland nurseries and its alternate host is wild grasses. Results of insecticidal studies on the control of this group of pests are scanty.The study being reported represents a preliminary investigation on the chemical control of the pest with some mention of its biology in this country.

LIFE HISTORY, HABITS AND NATURE OF DAMAGE

The paddy stem fly is rarely observed in the field except during the early stages of cultivation, following prolonged spells of drought or when there is a shortage of rain or irrigation water during the seedling stage of the paddy. During heavy infestations of paddy seedlings by this pest, sweepings of neighbouring grasses and weeds have failed to reveal the presence of the insects on these plants.

The fly lays its eggs singly on the leaf blades of paddy seedlings. The eggs are small oval-elongated and pure white in colour. They hatch in about 2 days and the maggot bores its way into the growing shoot and makes its way within the stem of the seedling to the base of the plant. This attack results initially in the yellowing and withering of the central shoot of the rice seedling. In the earlier

stages of the attack only the central shoot shows signs of damage but as the maggot approaches the base of the plant the tissues of the stem gradually turn brown and rot. Paddy seedlings up to 2 or 3 weeks old are usually attacked while older paddies are ignored by this pest.

The larval stage lasts about 1 week and is spent entirely within one seedling. Larvae may either emerge from the base of the stem of the seedlings or remain within it to pupate. Pupation lasts about one week.

As mentioned earlier the pest characteristically appears on rice seedlings after prolonged spells of drought or on tracts where irrigation or rain water is in short supply during the seedling stage of the crop. In recent times highland rice nurseries have been introduced and the incidence of the stem fly attack on such nurseries has become increasingly apparent.

INSECTICIDAL CONTROL

The earliest recommended control measures against this pest involved the flooding of attacked tracts of rice seedlings for 24 hours to kill the maggots within the stem. However apart from the relative inefficacy of flooding for the control of maggots, the fact that pest incidence coincides generally with lack of water rules out the possibility of using this measure extensively. The older chlorinated hydrocarbon insecticides like gamma BHC and DDT were recommended for the control of the pest but with little positive results except at the stage when the maggot has completed its damage and is emerging from the plant to pupate in some cases.

Once the maggot has entered the paddy seedling control of the pest will only partially save the seedling bases for tillering but damage to the main plant is already done. Control of ovipositing flies and hatching larvae on the other hand would give the most valuable results. More often than not however the presence of the pest is only recognised by the time withering of the central shoots has started and if this is detected early enough effective control of the maggots at that stage can save the crop.

An extremely heavy infestation of the paddy stem fly on the paddy seedling crop in the North-Central province during the *maha* cultivation of 1956-57 provided ideal conditions for testing a series of organophosphorus insecticides for either their direct penetrant or systemic action in controlling the pest. The paddy seedlings were 3 weeks old and 6 to 8 inches high. The seeds had been drilled in rows spaced about 4 inches apart. Each test treatment was conducted on an

area of 320 square feet involving six rows of paddy seedlings. Test plots were demarcated in the field with barrier plots between treatments consisting of 6 rows of seedlings.

The insecticides tested were parathion, gusathion, dipterex, malathion, diazinon, ekatin and two test organophosphorus compounds-numbers 4755 and 4756, supplied by Fakenfabriken Bayer, Leverkusen. Malathion and diazinon, not generally being penetrant insecticides, were expected to give poor control of the maggots within the stems of the rice seedlings, but were used to provide an index for comparison of the activity of the other insecticides. Parathion, gusathion and dipterex are especially notable for their penetrant action when administered on the rice plant, while ekatin and metasystox and compounds 4755 and 4756 were systemic insecticides. All these products promised satisfactory control of the maggots within the rice seedlings.

The test insecticides were all of the emulsifiable concentrate formulation. The prepared emulsions were applied as drenching sprays on to the plants and sufficient run-off was permitted to allow for permeation of the insecticidal fluid into the soil around each plant. The rate of application was about sixty gallons of spray per acre.

Twenty-four hours after treatment seedlings apparently affected by stem fly were collected at random from several locations within each of the test plots. By careful dissection of these seedlings 20 maggots were extracted from plants of each test plot and then examined for mortality. Mortality counts of maggots were likewise taken 48 and 72 hours after the spray treatments. The data obtained in this investigation are given in Table 1.

The order of effectiveness of those insecticides giving satisfactory control of the pest at low dosages may be expressed as follows in decreasing order of effectiveness : ekatin = (roughly) parathion = gusathion ——→ dipterex.

DISCUSSION

The results of this trial show that the two penetrant and systemic organophosphorus insecticides parathion, gusathion and ekatin respectively are most effective in killing stem fly maggots within the stems of the rice seedlings. Among the non-penetrant contact organophosphorus insecticides, malathion and diazinon were relatively ineffective for controlling the pest with the former markedly ineffective even at very high concentrations. Of the other systemic insecticides tested, the Bayer Compounds 4755 and 4756 and Metasystox gave very poor results. Dipterex, the other organophosphorus

TABLE 1—Mortality of Stem Fly Maggots within Stems of Rice Seedlings after Spraying of Seedlings with a Series of Insecticides

INSECTICIDE	*Formulation and Source of Product*	*Per cent Active Ingredient in Spray*	*Per cent Mortality of Maggots after Sprays*		
			24 Hrs.	*48 Hrs.*	*72 Hrs.*
Ekatin ..	20% E.C.* ..	0·0013	20	40	45
	Sandoz, Ltd. ..	0·0026	25	50	65
	Basle ..	0·0039	100	100	100
Parathion ..	46·7% E.C. ..	0·0031	90	100	100
	Bayer ..	0·0062	100	100	100
	Leverkusen ..	0·0093	100	100	100
Gusathion ..	20% E.C. ..	0·0013	35	55	90
	Bayer ..	0·0026	35	80	100
	Leverkusen ..	0·0039	40	100	100
Dipterex ..	50% E.C. ..	0·006	60	100	100
	Bayer ..	0·012	80	100	100
	Leverkusen ..	0·018	80	100	100
Diazinon ..	60% E.C. ..	0·008	20	40	50
	Geigy, Ltd. ..	0·016	25	55	60
	Basle ..	0·024	60	80	80
Malathion ..	50% E.C. ..	0·013	0	0	15
	American ..	0·026	0	15	20
	Cyanamid ..	0·039	0	35	30
	New York ..	—	—	—	—
Metasystox ..	50% E.C. ..	0·0033	0	10	10
	Bayer ..	0·0066	10	20	30
	Leverkusen ..	0·0099	35	50	65
Compound 4755 ..	65% E.C. ..	0·0022	5	20	30
	Bayer ..	0·0044	25	30	55
	Leverkusen ..	0·0066	40	55	60
Compound 4756 ..	50% E.C. ..	0·0033	0	25	40
	Bayer ..	0·0066	15	40	40
	Leverkusen ..	0·0099	15	40	50
Untreated Checks	—	—	0	0	0
		—	0	0	0
		—	0	0	0

* E.C. = Emulsifiable Concentrate.

insecticide which possesses penetrant properties similar to those of parathion, was roughly half as effective as ekatin, gusathion and parathion in killing the maggots of the stem fly within the stems of rice seedlings.

These results indicate that ekatin, parathion, gusathion and dipterex are ideally suited for the control of stem fly infestations on a field scale as they are all effective at economic dosage levels. The value of the application of these chemicals for the control of the pest will however depend to a large measure upon the very early detection of the presence of the pest as indicated by incipient withering of the central shoot and immediate application of the insecticidal spray. This will save the plant for tillering and regeneration of new growth. Application of the insecticidal treatment when the entire stem has been damaged and the maggots are approaching pupation will kill the pest but with no benefit to the seedlings which will not recover.

The present investigation has concerned itself with methods of controlling existing infestations of stem fly maggots within the rice seedlings. The most valuable application of insecticidal treatments will however be for the prevention of entry of the freshly hatched maggots into the growing shoot. Further insecticidal trials are to be carried out with this end in view.

SUMMARY

(1) Tests have been carried out for the control of infestations of paddy stem fly maggots within rice seedlings using 9 organophosphorus contact and systemic insecticides.

(2) The insecticides giving good kill of the maggots within stems could be arranged in the following descending order of effectiveness when compared dose for dose; ekatin= (approx.) parathion → gusathion → dipterex.

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METEOROLOGICAL REPORT

SUMMARY FOR OCTOBER-DECEMBER, 1957

WIDESPREAD DROUGHT conditions of September continued during the first part of October too, causing grave hardship. Relief came with the commencement of afternoon and evening thundershowers about the 11th. At the beginning they occurred mainly in the south-western parts, but soon increased in intensity and extent, and were widespread from about the 15th. Rainfall on the 20th was considerably heavy, a large number of stations recording falls over 3 inches. Thunderstorms were very severe on some days, and were responsible for a few deaths. Rainfall for the month ranged mainly between 5 and 15 inches. There were larger totals among the south-eastern hills, in the neighbourhood of Anuradhapura and Matale and scattered in the south-western parts, the largest being 25.17 inches at Blackwood Estate (Haputale). The neighbourhood of Hambantota and Puttalam recorded the least rainfall, with totals below 5 inches. The rainfall was irregularly distributed on both sides of average. The larger deficits ranging from 5 to 10 inches, occurred in the south-western hill-country and neighbourhood, while the larger excesses, also ranging from 5 to 10 inches, occurred in the extreme south of the Island, among the south-eastern hills and in the north-central parts. A hailstorm was reported from Maho on the 28th.

Afternoon and evening thundershowers, which were a feature of the October weather, continued throughout November too, resulting in widespread rain over the Island. The rainfall was heavy on the 4th, 6th and 29th, particularly on the 29th when about 50 daily falls over 5 inches were recorded. This last rainfall caused considerable damage to house and property in the Jaffna Peninsula. The monthly totals ranged generally from 15 to 30 inches. Greater totals occurred on the north-eastern slopes of the hills and in the south-western mid-country, the greatest being 46.07 inches at St. Martin's Upper Estate. The rainfall was least in the extreme south of the Island and in Chilaw and Puttalam districts, where the totals at a few stations were below 10 inches. The rainfall was well above normal over a vast area of the Island, the excesses being mostly above 5 inches. Greater excesses, those exceeding 10 inches, occurred on the north-eastern slopes of the

hills, in the south-western mid-country and scattered in the north-eastern low country to north of Trincomalee. There were a few scattered deficits.

The outstanding feature of the weather during December was the occurrence of a depression over Ceylon, resulting in unprecedented rains and consequent devastating floods over a very wide area covering the whole northern half of the Island, the Gal Oya valley and the Batticaloa District. During the first half of the month the weather conditions were of the north-east monsoon type, with rain mainly confined to the north-eastern parts. About the 17th, conditions became unsettled due to a trough of low pressure in South Bay of Bengal, and there was an increase of rainfall in the north-east. This increase reached a climax on the 19th, when the whole north-eastern hill-country received amounts ranging from 5 to 10 inches. Thereafter too the rainfall continued moderately heavy, and the trough concentrated into a depression off the east coast of Ceylon on the 24th, giving heavy rain exceeding 5 inches over a wide area in the eastern parts extending from Diyatalawa-Tirrukovil in the south to Trincomalee-Mankulam in the north. There were heavier falls ranging from 10 to 15 inches in the Gal Oya catchment area and in places in the north-central parts. The region of heavy rain shifted north-westwards gradually, and the falls exceeding 5 inches occurred over the whole of the Northern Province and over a greater part of North-Central, North-Western and Central Provinces on the 25th. Heavier rain on this day occurred in a central area extending from Madawachchiya to Elephant Pass, the amounts ranging from 10 to 15 inches. A major portion of the affected area therefore received over 15 inches of rain during these two days, the receipts at several stations in the north-eastern hill-country exceeding 20 inches. This heavy rain was also responsible for several large-scale earth slips in different parts of the Island, which buried under them a few houses together with the property and inmates within. The greater monthly totals of rainfall during December occurred in the north-eastern parts, where almost all the stations recorded over 30 inches for the month. At a number of these stations the totals exceeded 60 inches, in the case of some of them these totals being the highest on record for December. Thus, the totals of 88.07 inches at St. Martin's (Upper) Estate and 74.06 inches at Kobonella Estate (both in Rangala area) are the highest December totals at these two stations during 71 and 76 years of observations respectively, both recording their previous highest 70 years ago in 1887 (85.80 inches at St. Martin's and 67.61 inches at Kobonella). Similarly, 60.27 inches at Gammaduwa Estate is the highest in 82 years, the previous highest of 50.50 inches occurring 80 years ago in 1877. The highest monthly totals in 1957 were 107.58

inches at Forset Hill Estate and 91.74 inches at Dooroomadella Estate (Bungalow) both in Gammaduwa, 88.07 inches at St. Martin's (Upper) Estate (Rangala), 85.63 inches at Habarana and 84.86 inches at Madugoda. The rainfall decreased gradually towards the west and the south, the monthly totals in the Southern Province and in the neighbourhood of Chilaw being of the order of 15 inches only. The rainfall was least in the neighbourhood of Matara, where the monthly totals were below 10 inches. The rainfall was very much above normal in the north-eastern parts, the totals recorded being more than three times the average. The excesses, consequently, exceeded 40 inches at these stations. In the south-western parts too the rainfall was well above normal, the excesses being generally of the order of 10 inches. There were a few slight deficits also, in the neighbourhood of Matara. The number of daily falls over 5 inches exceeded 500, a great majority of them occurring on the 24th and 25th.

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	OCTOBER								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Number of days	Offset
Anuradhapura ..	91·3	+2·4	73·9	+0·4	70	93	13·89	17	+4·17
Badulla ..	83·5	+0·7	65·7	+0·2	70	95	9·90	17	+1·01
Batticaloa ..	86·4	—0·6	75·4	+0·1	78	91	6·93	14	—0·26
Colombo ..	85·9	+1·0	74·4	—0·4	80	95	9·08	20	—4·63
Diyatalawa ..	77·4	+1·1	60·3	—0·2	74	91	13·87	19	+4·69
Galle	83·4	+0·5	75·3	—0·1	81	88	11·04	21	—1·01
Hambantota ..	85·2	—1·0	76·0	+0·7	80	91	5·49	14	+0·73
Jaffna	85·8	+0·1	78·0	+0·4	78	84	13·44	15	+4·24
Kandy ..	85·0	—0·4	67·8	—0·2	73	95	10·97	16	—0·64
Kankesanturai ..	86·9	0	77·3	+0·2	78	89	7·03	19	—2·59
Kurunegala ..	89·4	+2·2	74·1	+0·9	69	90	10·26	19	—4·60
Mannar ..	87·0	+0·1	78·3	+1·0	78	86	9·34	15	+2·76
Nuwara Eliya ..	69·1	+1·5	52·0	—0·2	78	88	8·89	18	—0·87
Puttalam ..	88·5	+2·2	76·5	+0·9	72	86	4·45	15	—2·98
Ratmalana ..	86·4	+1·2	75·6	+0·7	75	91	10·93	25	—2·27
Ratnapura ..	88·3	+1·2	72·8	0	73	90	10·77	23	—7·24
Talawakele ..	73·1	—0·1	57·9	+0·1	78	91	9·45	16	—0·61
Trincomalee ..	89·2	+1·2	76·4	+0·8	72	84	13·21	18	+3·66

	NOVEMBER								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Number of days	Offset
Anuradhapura ..	86·0	+0·2	73·1	+1·7	84	98	20·81	28	+10·14
Badulla ..	79·8	+0·5	67·2	+1·8	82	95	20·62	29	+10·37
Batticaloa ..	83·4	—0·8	74·4	+0·2	85	95	20·28	26	+ 6·42
Colombo ..	85·3	+0·1	73·9	+0·6	80	95	17·35	26	+ 4·26
Diyatalawa ..	74·7	+0·4	61·4	+0·6	86	97	17·34	30	+ 6·92
Galle	83·9	+0·3	73·6	—0·6	82	93	13·69	22	+ 1·68
Hambantota ..	84·8	—0·6	74·5	+0·5	82	93	14·46	20	+ 6·89
Jaffna	84·3	+0·2	75·5	+0·7	81	88	24·02	27	+ 6·75
Kandy ..	83·4	+0·5	68·6	+1·2	80	95	18·25	30	+ 7·55
Kankesanturai ..	84·1	—0·1	75·8	+0·3	83	93	21·51	23	+ 4·37
Kurunegala ..	86·8	—0·1	72·8	+0·9	78	98	21·81	26	+ 9·42
Mannar ..	84·2	—0·4	76·5	+0·8	82	91	16·55	25	+ 6·36
Nuwara Eliya ..	69·2	+1·4	53·9	+2·8	82	91	16·19	29	+ 7·00
Puttalam ..	86·4	+0·7	74·1	+1·0	80	93	17·83	28	+ 7·70
Ratmalana ..	86·0	—0·4	73·9	+1·1	77	93	26·55	24	+14·43
Ratnapura ..	88·7	+0·9	72·8	+0·6	76	90	22·51	26	+ 7·72
Talawakele ..	73·2	—0·3	59·0	+2·0	87	94	12·18	28	+ 3·68
Trincomalee ..	84·2	+0·6	76·0	+1·2	82	88	37·54	24	+23·60

	DECEMBER								
	Temperature				Humidity		Rainfall		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Min. Temps.)	Total	Number of days	Offset
Anuradhapura ..	82·3	—0·9	72·4	+2·3	87	95	36·50	25	+28·98
Badulla ..	75·3	—1·3	67·3	+2·8	88	95	30·55	29	+19·32
Batticaloa ..	81·7	—0·3	74·8	+1·2	89	93	46·47	27	+29·48
Colombo ..	84·8	—0·7	73·4	+1·1	81	93	21·54	24	+15·93
Diyatalawa ..	70·5	—1·6	61·9	+3·3	90	94	23·70	27	+15·63
Galle	83·1	—0·5	73·2	—0·1	83	93	15·74	22	+ 7·92
Hambantota ..	83·2	—1·4	74·3	+1·3	84	95	18·89	19	+13·28
Jaffna	82·3	—0·2	74·6	+1·5	79	88	29·78	22	+19·39
Kandy ..	79·8	—2·0	68·5	+2·6	83	95	32·66	25	+23·79
Kankesanturai ..	82·4	—0·3	75·7	+0·9	84	88	33·14	20	+23·40
Kurunegala ..	83·7	—2·0	72·5	+1·8	80	95	23·70	21	+16·92
Mannar ..	82·1	—0·7	75·8	+0·9	82	88	24·40	22	+16·61
Nuwara Eliya ..	66·2	—1·5	54·8	+5·8	85	91	31·57	27	+23·76
Puttalam ..	83·7	—1·0	73·0	+1·7	81	85	27·46	24	+21·91
Ratmalana ..	85·6	—0·7	73·2	+1·5	80	93	22·17	24	+15·52
Ratnapura ..	86·3	—1·7	72·2	+0·6	79	90	18·96	25	+ 9·84
Talawakele ..	72·0	—1·5	60·0	+3·9	84	89	21·18	26	+16·00
Trincomale ..	81·7	+0·6	75·9	+1·0	82	86	29·81	27	+16·81